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Center for Urban and Regional Affairs

LAKE SANDY RESTORATION FEASIBILITY STUDY
(PHASE I)

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Definition of the Problem

During the end of the last and the first decade of this century a small lake, Lake Sandy, was situated in Columbia Park, NE Minneapolis. Exact information about lake parameters, such as depth and volume, is unavailable for the time of its existence. Lake Sandy ceased to exist as a lake in the early part of the century, certainly by 1919, for a number of not-well-documented reasons. Subsequently the area of the former lake has been a wetland, off and on, and more centely it has been graded, drained and maintained as part of a municipal golf course. Ever since its demise deliberation about its restoration has been strong. In the past few years the "Lake Sandy Restoration Committee" and the Northeast Planning Council with various Citizens Advisory Committees have been successful in regenerating interest and in initiating feasibility studies to rehabilitate the lake.

Objectives and Scope

This study investigates the hydrologic feasibility of reconstituting Lake Sandy in what is left of the old lake basin. In particular it will look into some of the historical accounts that may provide clues about the disappearance of the lake. The present topographic depression will be evaluated as to its capacity to contain and hold lake water. The hydrometeorologic inputs to the lake water balance will be estimated. The main question is whether under present climatic and hydrologic conditions an appropriate hydrology can be created to sustain a reconstituted lake in parts of the old Lake Sandy basin. This phase of the study does not address the limnologic or economic feasibility of a newly restored lake.

The scope of this phase of the study is to reconstruct the lake basin history based on archival materials, to obtain an overview of the surficial and bedrock geology from existing well logs and field inspection and to calculate the hydrologic balance of the lake with data on file from the State Climatology Office. No equipment-intensive field investigation such as deep drilling and sampling were envisaged in this phase, but recommendations for further studies will be made.

Case History

Several theories have been advanced about the drying up of Lake Sandy. These include drainage, change and diversion of surface runoff due to urbanization, lake bed destruction, and infilling.

A brief excerpt of documents pertaining to Columbia Park and Sandy Lake has been compiled by the Minneapolis Park Board (Columbia/Sandy Lake, not dated, 45 pages). The impression one gets from these excerpts is that the Superintendent of Parks was mainly interested in draining the lake and installing athletic fields or enlarging the golf course, which was considered more beneficial than a shallow lake. Early on after acquisition of Columbia Park drain tile were laid (1893) and connection to existing sewer systems were sought to accelerate drainage. This is partly documented by purchase orders for drain tile and its emplacement (1893-1894) and different attempts to connect the park to existing or new sewer lines (31st St. sewer line). As early as 1914 to 1915 problems of athletic field use are connected with drainage of the meadows (no lake then). In 1918 the park drainage system was connected with the Soo

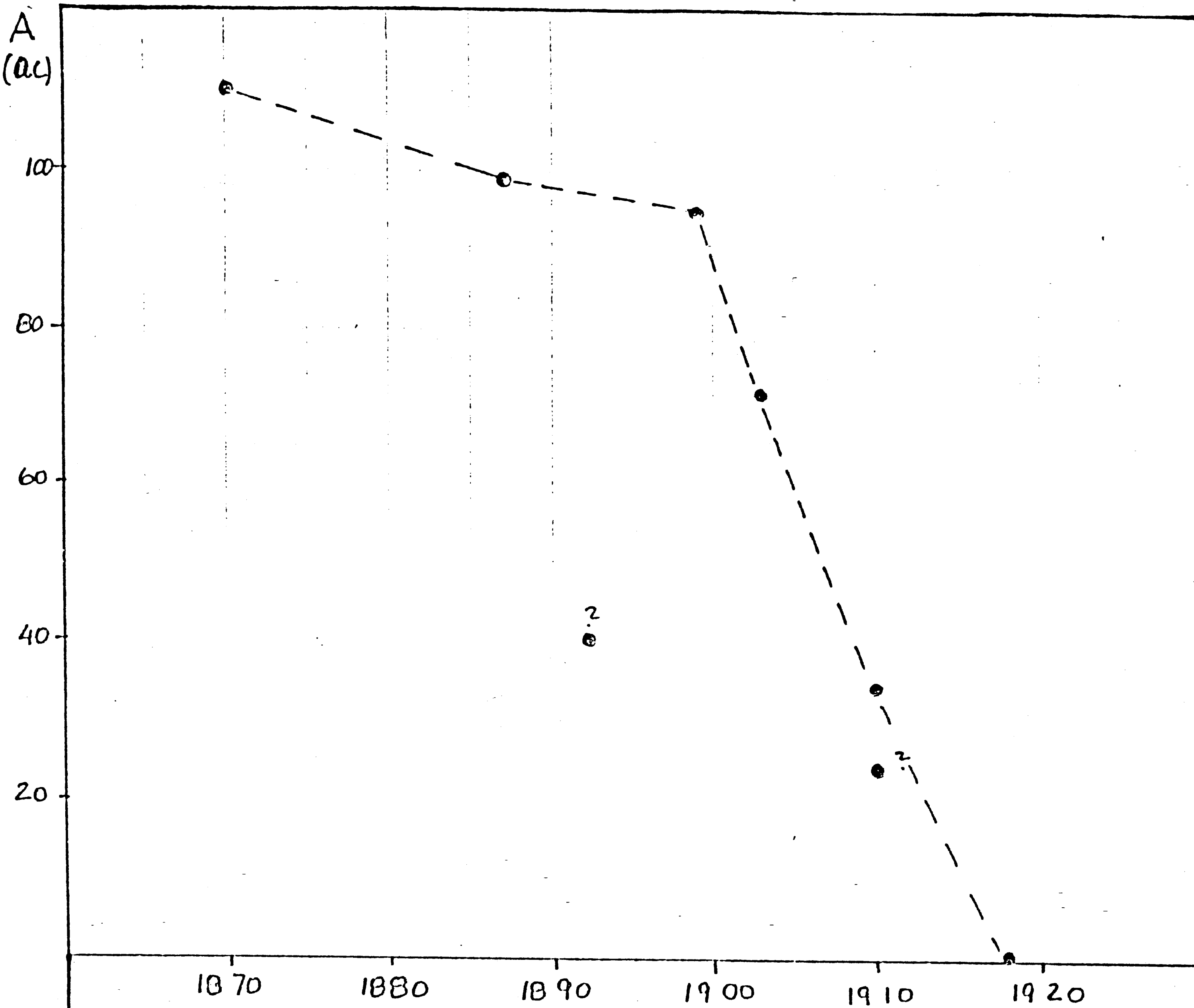
Line drainage system and the "meadow" was then considered dry enough for athletic activities. Not until the 1925 annual report are problems of wetness mentioned, in 1925 the problem of surface water disposal is again talked about.

From 1928 on citizens are requesting the regeneration of Lake Sandy or installation of swimming facilities. The meadow is plowed and seeded in 1937 and fairways installed in 1940.

Perusal of old maps or plates showing Sandy Lake has resulted in Figure 1. The lake outlines are shown on Figures 1b-1f. The lake's area at different times was measured and plotted (Fig. 1a). The oldest document is a map by the Surveyor General's Office in which an unnamed lake is situated between the east half of sec. 2 and the west half of sec. 1 (T29, R24). It is assumed that it depicts Sandy Lake but is somewhat inaccurate with respect to its location. Later maps correctly show it entirely located in sec. 2.

If the crude measures and representations represent reality one can see a slight decline in area - which is also indicative of a decline in depth until approximately 1900 (5 acres lost per decade), then a rapid decline takes place, 45 acres lost per decade or ten fold acceleration. This could be explained by the combination of the effects of drainage and diversion of surface runoff due to storm sewers and increased urbanization. The 40 acre value in 1892 is somewhat of a discrepancy - it is not measured but only mentioned in Wirth's report about the acquisition of Columbia Park. In any case, a rapid decline in water level is obvious.

No documentation that the lake level had been filled in by the dredgings of Lake of the Isles could be found. In a later section on present lake basin-area relationships it can also be seen that a substantial, albeit empty, basin



Lake Sandy Area vs Time

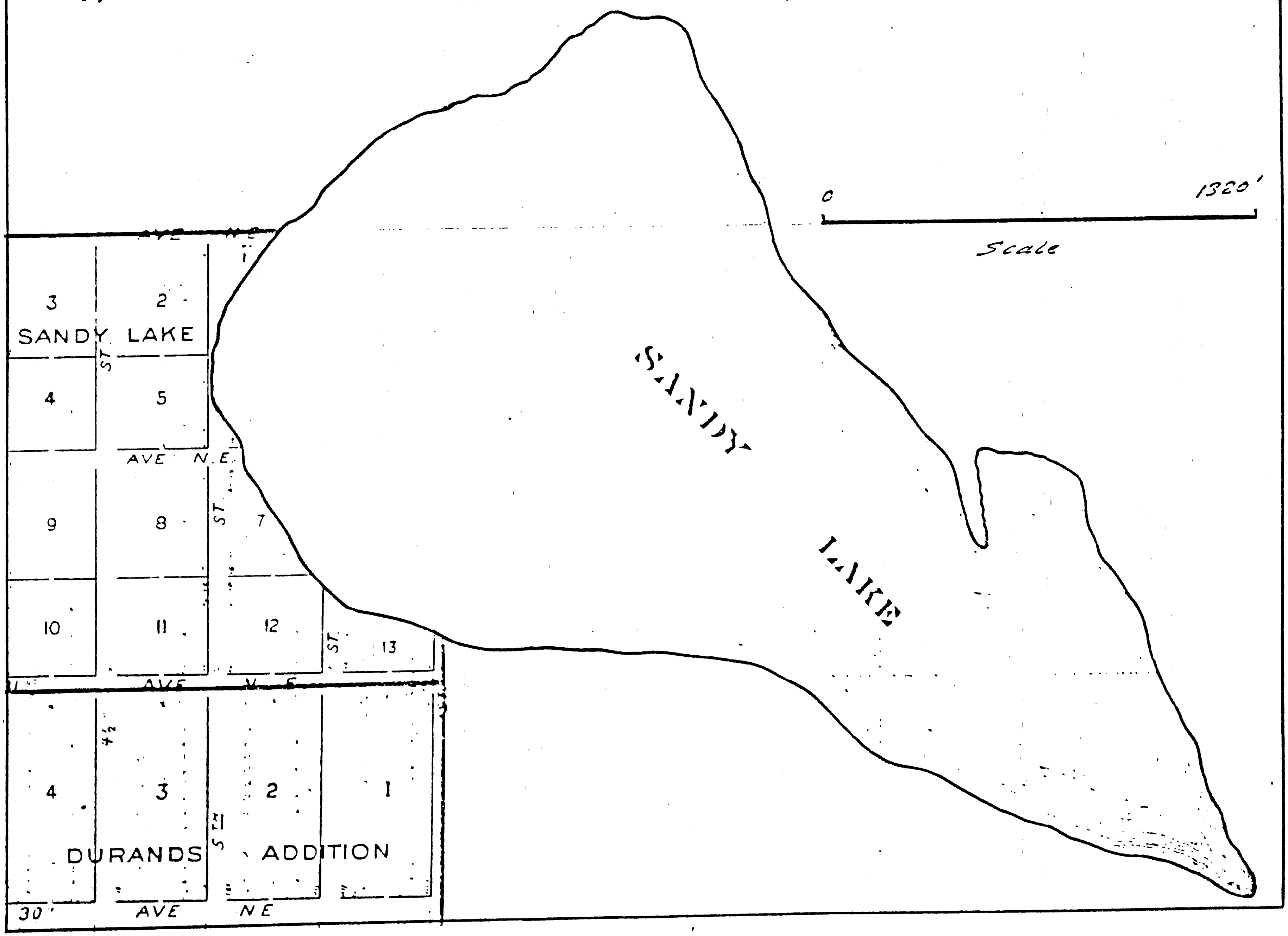
Sources:

1870	Map. Surveyor General's Office Unnamed Lake (Sec. 2 and 1)	110 ac
1887	Minneapolis (Plat Sec 2, T29, R24)	99 ac
1899	USGS 15' Topo Map (surveyed)	95 ac
1903	Minneapolis [James E. Eagan]	72 ac
1892	Quote T. Wirth	40 ac
1910	Comparative Area Diagram	34 ac
1910	28 Annual Report (Pk. Bd.)	24 ac
1918	36th Annl. Report (Pk. Bd)	DRY

FIG. 1-8

(FIG. 1.6) : Year 1837

Sec. 2, T 29N, R 24 W



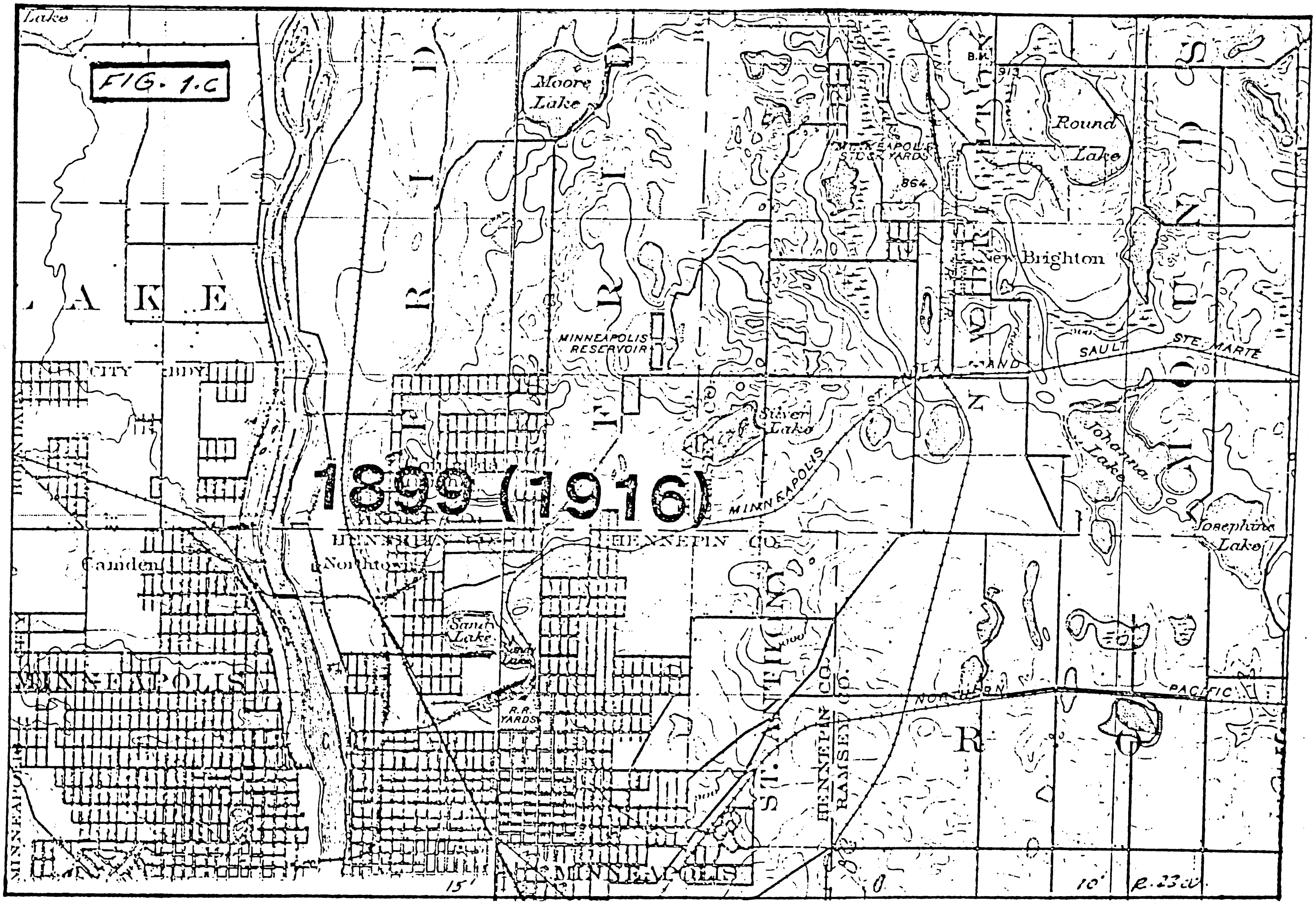
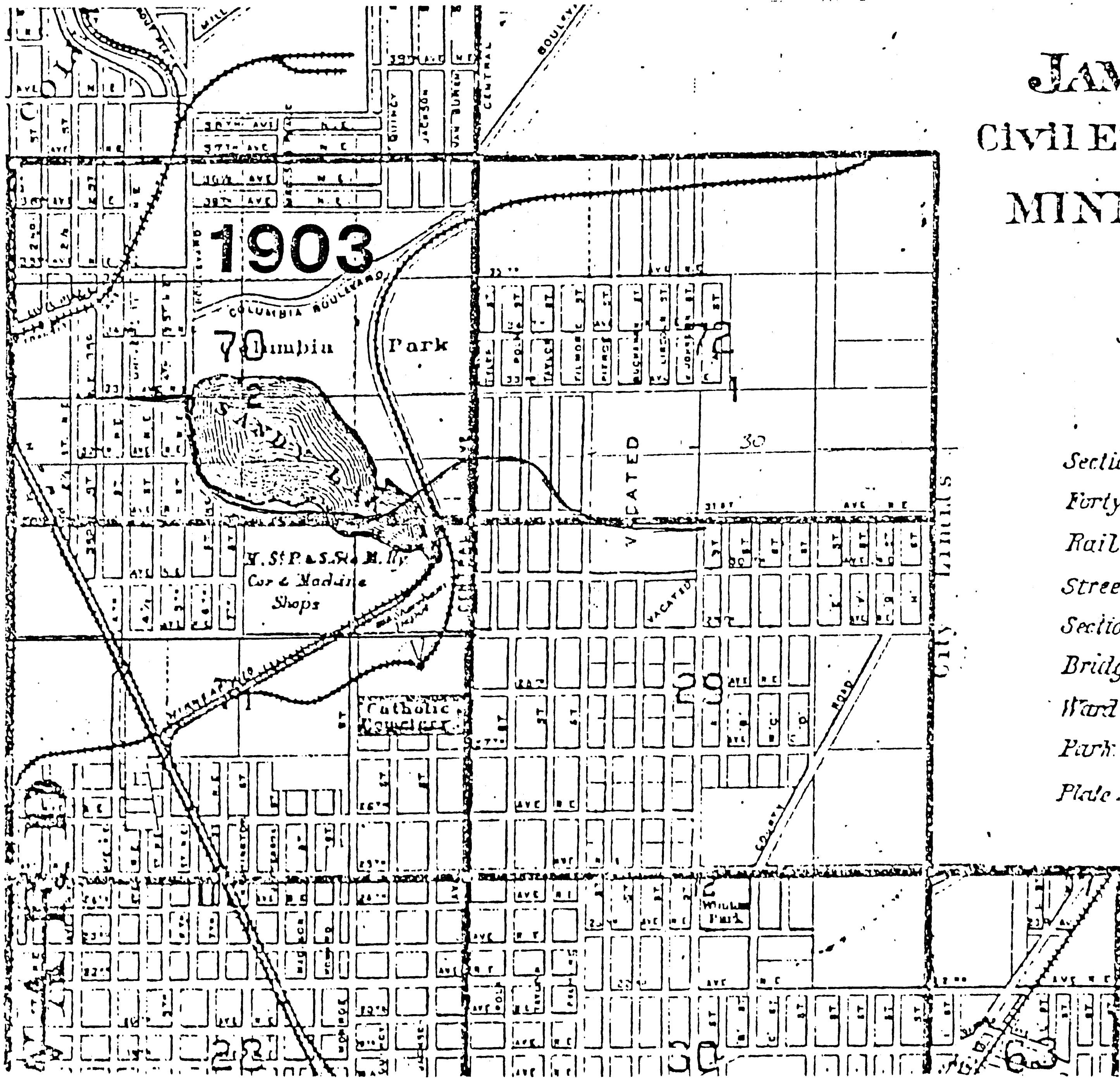


FIG. 1.C
1899 (1916)
Moore Lake
Round Lake
B.M. 913
MINNEAPOLIS STOCK YARDS
864
New Brighton
MINNEAPOLIS RESERVOIR
SAULT STE. MARIE
Silver Lake
MINNEAPOLIS
Johanna Lake
Josephine Lake
LAKE
CITY BDY
HENNEPIN CO.
Camden
Northtown
Sandy Lake
R.R. YARDS
MINNEAPOLIS
NORTHERN PACIFIC
HENNEPIN CO.
RAMSEY CO.
15'
10'
R. 23 W.



Compiled by

JAMES E. EGAN,

Civil Engineer & Surveyor

MINNEAPOLIS, MINN.

1903

Scale: 1 inch to 1800 feet.

Explanations

Section Lines,

Forty Lines,

Rail Roads,

Street Car Lines, ... *Blue Lines*

Section Numbers, ... 1, 36.

Bridges

Ward Limits, ... *Solid Tints*

Park System, ... *Green*

Plate Numbers and Boundaries ... *Red.*

FIG. 1.d

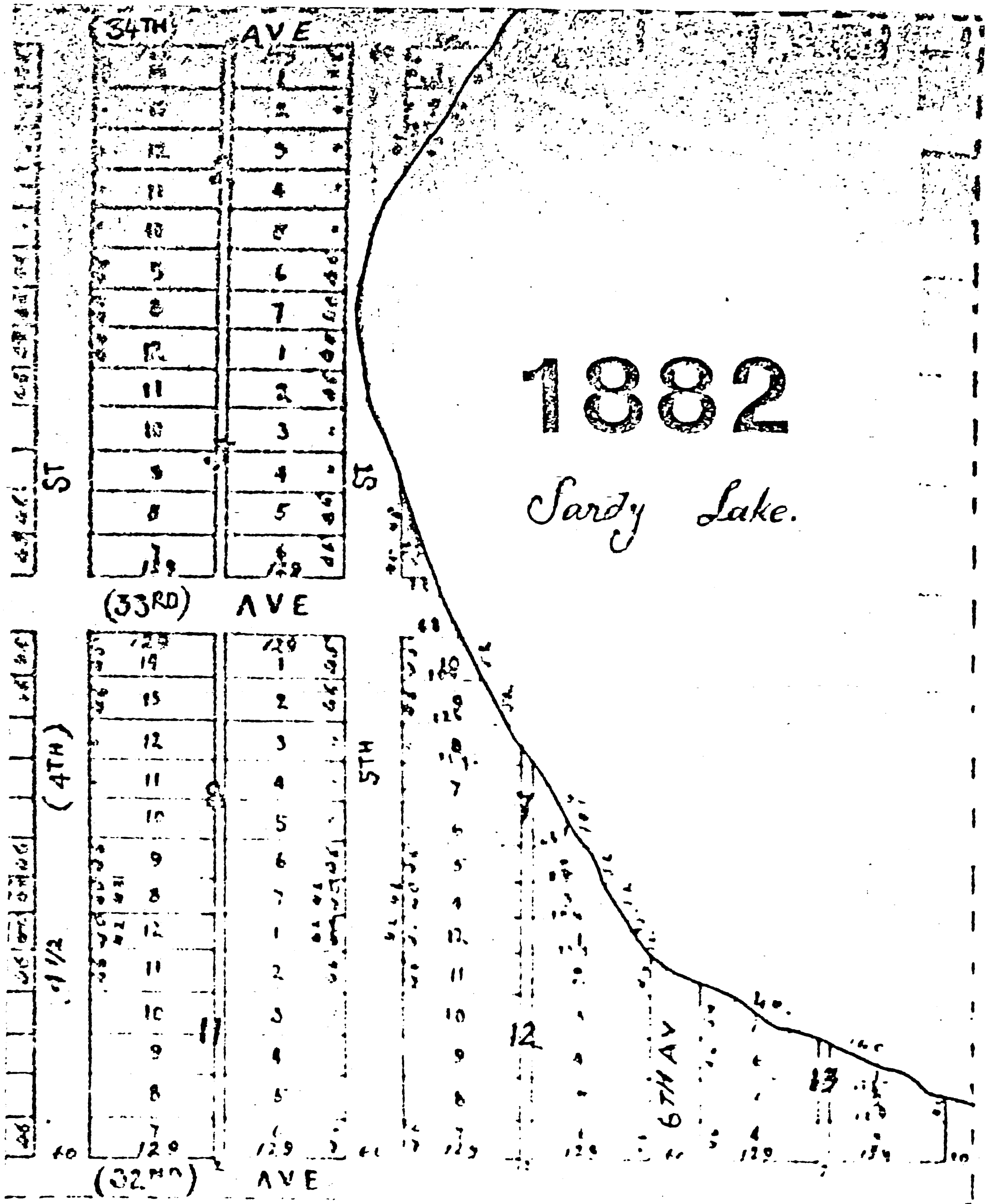


FIG. 1-e

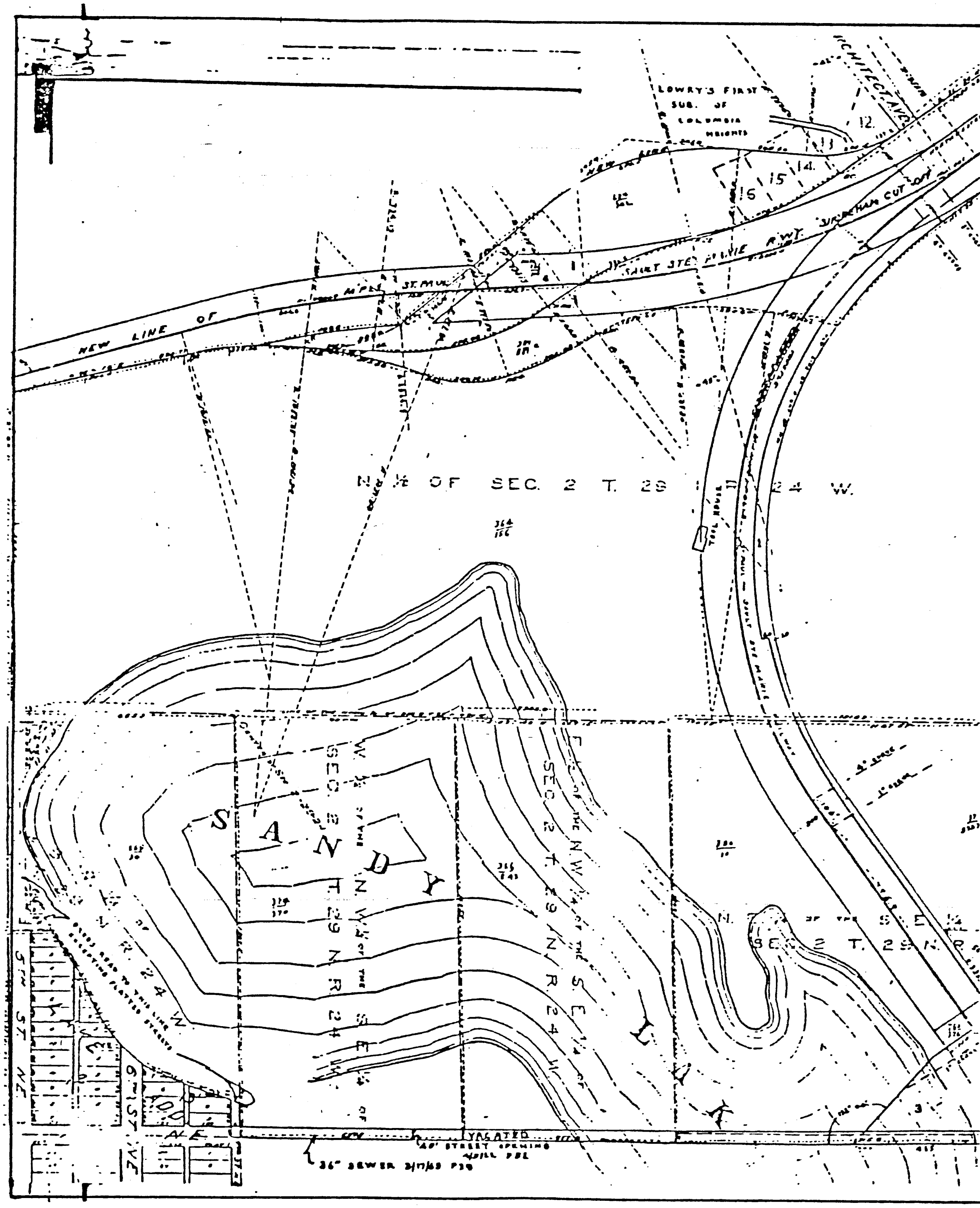


FIG. 1-f (Undated)

remains in existence. If the filling due to the construction of St. Anthony Parkway and the Soo Line switch yard is accounted for, the approximately similar lake areas are found, about 60 to 70 acres.

The main reason for disappearance of the lake would therefore be drainage and modification of surface runoff. Whether lowering of the water table is a contributing factor could not be established in this study. There seems to be, however, more or less constant groundwater (dry weather) discharge in some of the open water areas in the center of the lake bed (between 13th and 15th holes).

Geologic Background

The geologic materials which constitute the looser, unconsolidated surficial deposits and the more competent bedrock form the container for lake basins and their hydrologic characteristics determine the rate of flow or seepage of groundwater under natural conditions.

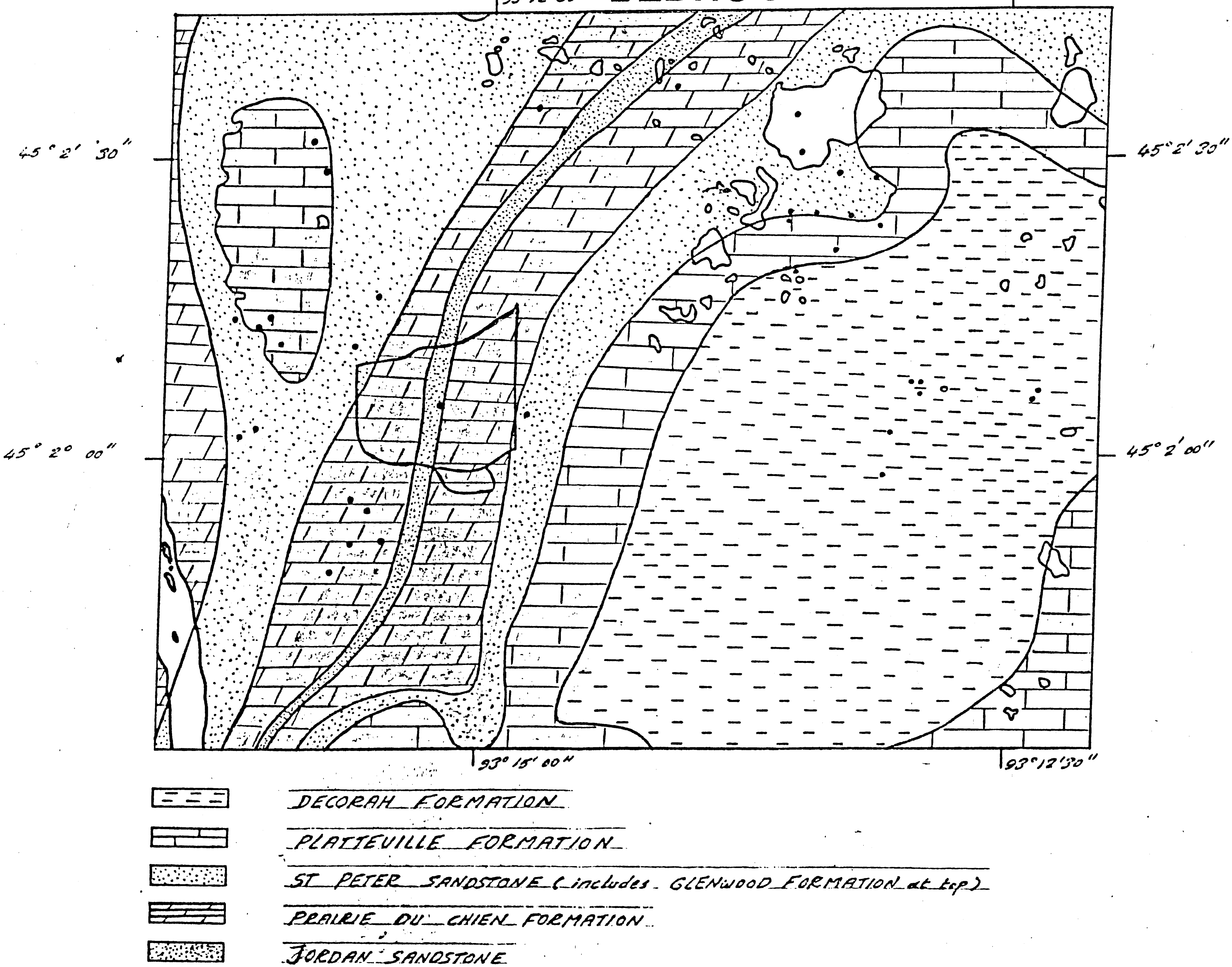
Bedrock

Figure 2 shows a bedrock geologic map of the region with the study area outlined. The main subcropping units are the Prairie du Chien formation and the Jordan sandstone. The Prairie du Chien contains the Shakopee dolostones, which are fairly permeable, mainly through fractures and joints. The narrow band of Jordan flanked by younger formations is indicative of a buried bedrock valley. Many bedrock valleys in the Twin Cities area were preferred locations of ice-block lake formation during the last glaciation. The Cedar-Isles-Calhoun-Harriet system, for example, is located on such a buried valley.

Groundwater interaction between the bedrock and the drift could not be established with present information.

FIG. 2

BEDROCK



Surficial Deposits

The surficial deposits that form the immediate lake bed are basically glacial drift. Their regional distribution is given in Figure 3 with a lithologic description of the drift formations. A number of representative well logs are given in Figure 4. They show that a rather thick deposit of glacial material overlies the bedrock, anywhere between 100 and 200 ft. Exact depth to bedrock near the park is indeterminate, since the wells only finished in the drift.

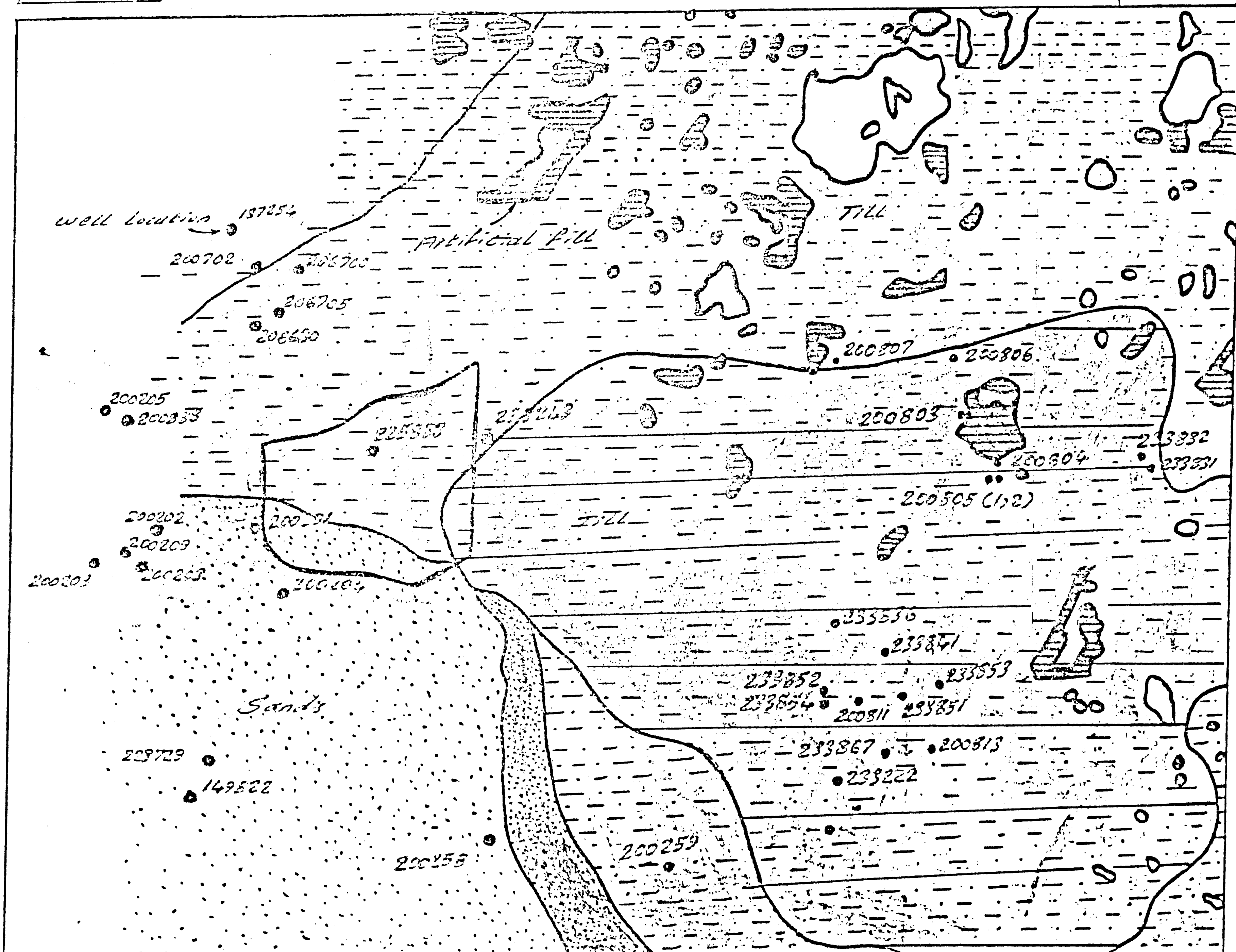
The material is basically sandy till, sandy materials, clay and organics. This is fairly typical. Columbia Park consists of sandy or sandy till hills or hummocks with depressions in between. The depression would first receive the fine materials washed off the hillside as bottom fill and then obtain organic growth and deposits. This makes the depression susceptible to collect and hold water.

In the course of this study samples were taken on the hilly slopes and hills where soil formation is at a minimum. The material is fine sand to sandy till, material that would be fairly permeable to groundwater flow and infiltration. The material in the old lake bed could not be sampled to the depths that go beyond artificial or cultural influence. The top soil is basically artificially conditioned for the requirements of the golf course, therefore it is not indicative of the deeper underlying materials. These, from the drill logs, vary between sandy materials to clays. In order to obtain more specific information split spoon drill samples should be acquired.

By itself the material filled into the swales between the hummocks should be of fairly low permeability to retain collected water.

FIG. 3.a

DRIFT



well location
187254
200702
206705
Artificial fill
Till
200807
200806
200205
200803
233832
200804
233831
200805 (1,2)
Till
200202
200209
200203
Sands
233841
233852
233553
233854
200811
233851
233867
200813
233222
228729
149822
200258
200259

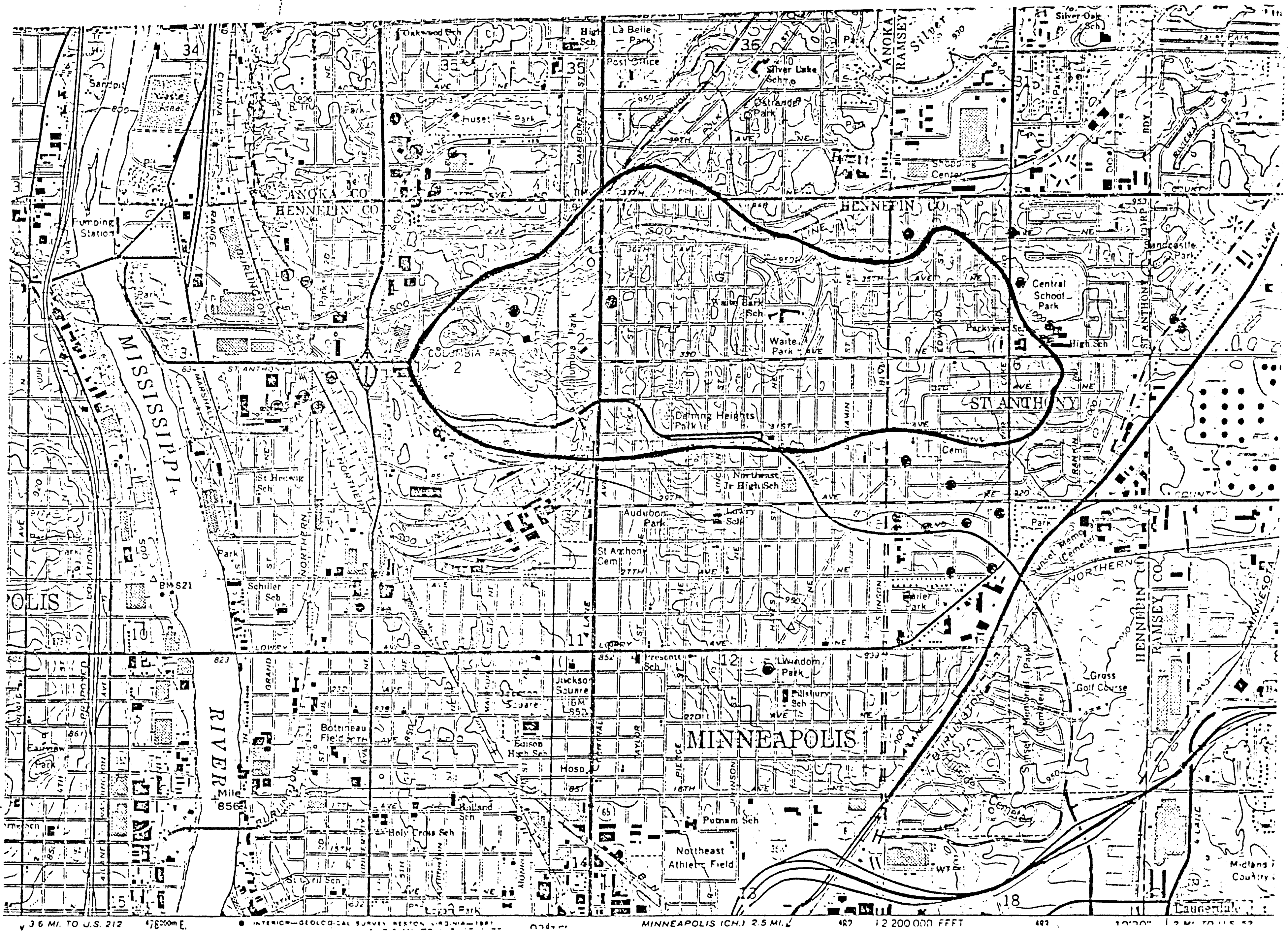
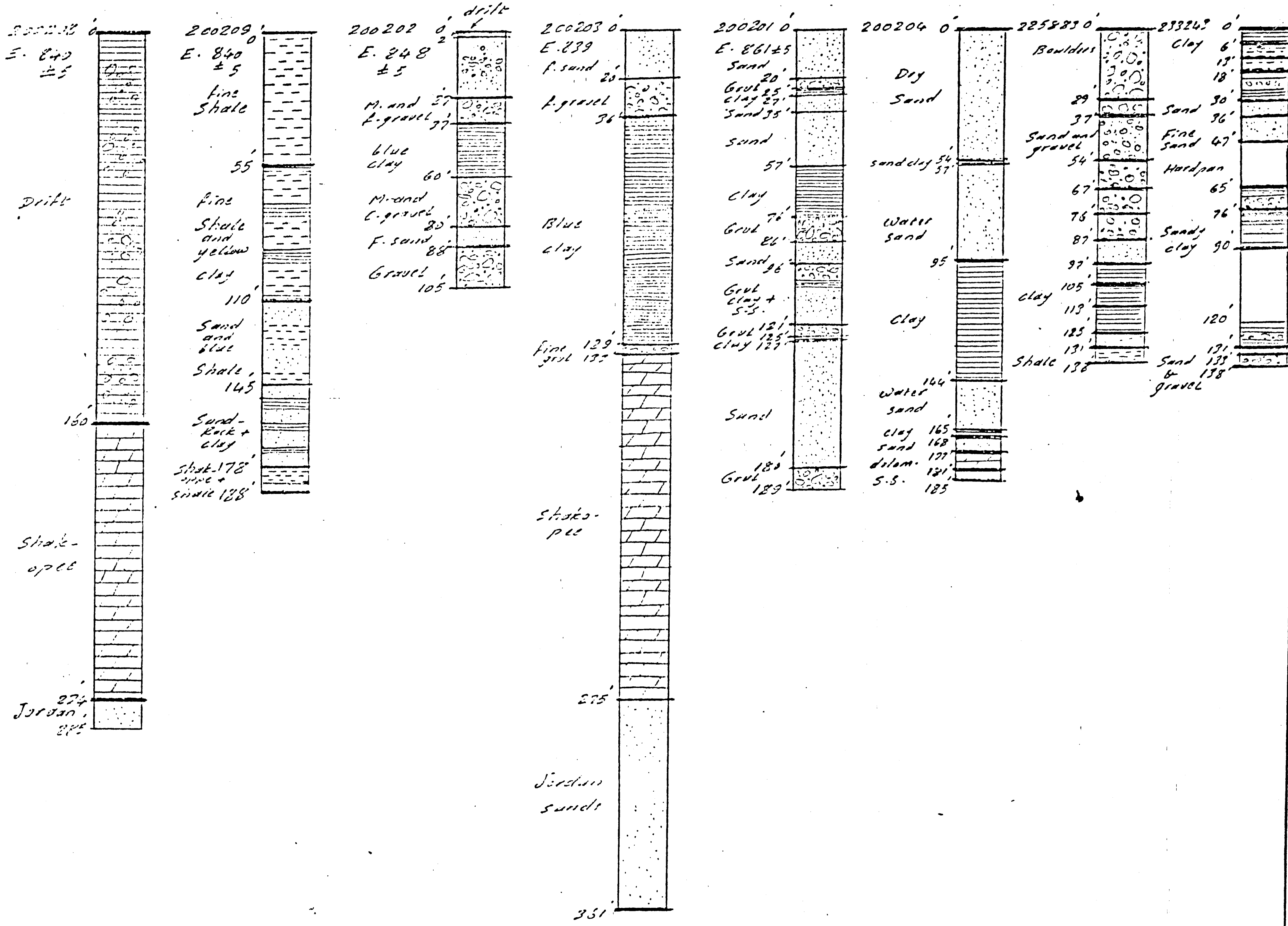


FIG. 3.6 : watershed area



Drift
Shak-opee
Jordan
200209
E. 840 ±5
Fine Shale
55
Fine Shale and yellow clay
110
Sand and blue Shale
145
Sand-Rock + clay
Shale 178
Shale 188
200202
E. 848 ±5
drift
M. and f. gravel
blue clay
60
M. and C. gravel
F. sand
88
Gravel
105
200203
E. 839
f. sand
f. gravel
36
Blue clay
Fine grvl
129
Shako-pee
275
Jordan sands
331
200201
E. 861±5
Sand
Grvl
clay
Sand
57
Clay
Grvl
Sand
Grvl clay + S.S.
Grvl
clay
Sand
Grvl
189
200204
Dry Sand
sand clay
Water sand
95
Clay
144
Water sand
clay 165
sand 168
dolom.
S.S.
185
225883
Boulders
Sand and gravel
54
67
78
87
97
clay
105
113
125
131
Shale 138
233243
Clay
Sand
Fine Sand
Hardpan
65
76
Sandy clay
90
120
Sand & gravel
138

FIG. 4

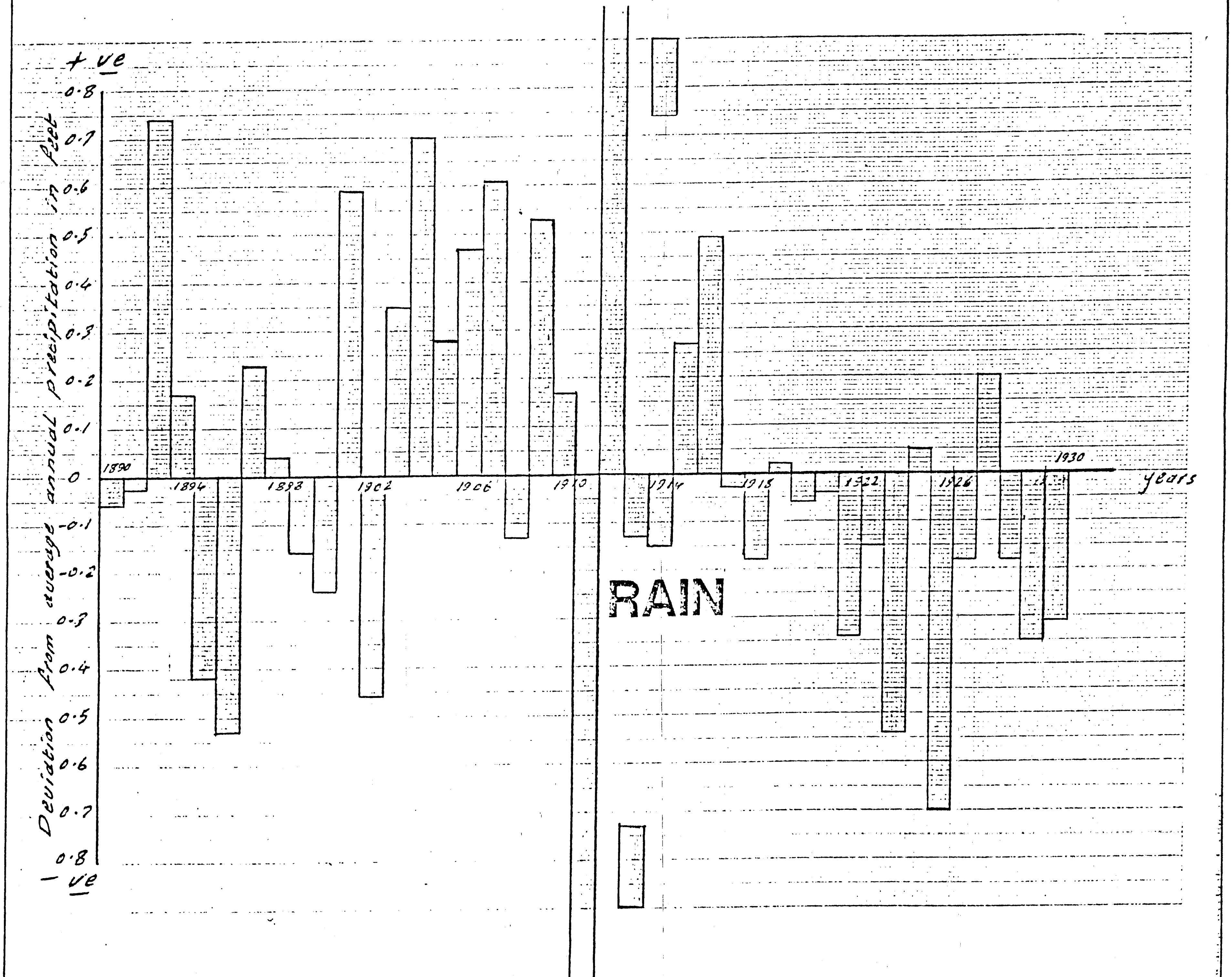
From the cursory overview of the geology it can be concluded that the general geomorphology and landscape in the park would favor the creation of lakes and wetlands, and that groundwater flow and infiltration through the more permeable deposits in the hills and hummocks could further sustain these water and wetland bodies.

Hydrometeorology

Whether a depression in the surface, even with a low permeability bottom, will actually become and remain a lake depends on climatic conditions. The elements of the hydrologic cycle which constitute this balance are precipitation, evapotranspiration and runoff.

Precipitation: The longest available and continuous record for the Twin Cities is the National Weather Service Station (#15435) now at the Minneapolis-St. Paul Airport. Earlier data have been collected from different sites, but the results are compatible and thus records date back to 1836 for precipitation and 1819 for temperature. Figure 5 gives the yearly deviation from the average precipitation for the period of interest 1890 to 1930. From its inspection the years when the lake went down actually were wetter than average. Even though the year 1910 had the lowest precipitation (only 10.21 in) it was followed by the year of highest precipitation (1911 = 40.44 in) so that any drought induced lake level decline should immediately have been offset.

Figure 6 shows a frequency-duration curve on probability paper. The data are taken from 1900 to 1984. The significance of the graph is that it tells with what frequency or what probability different annual precipitation values can be expected. For example, the probability that the average rainfall each year will exceed 20 inches is 90%, or it has a recurrence period of 10 years.


+ ve
0·8
0·7
0·6
0·5
0·4
0·3
0·2
0·1
0
-0·1
-0·2
0·3
0·4
0·5
0·6
0·7
0·8
- ve
Deviation from average annual precipitation in feet
1890
1894
1898
1902
1906
1910
1914
1918
1922
1926
1930
years

RAIN

FIG. 5

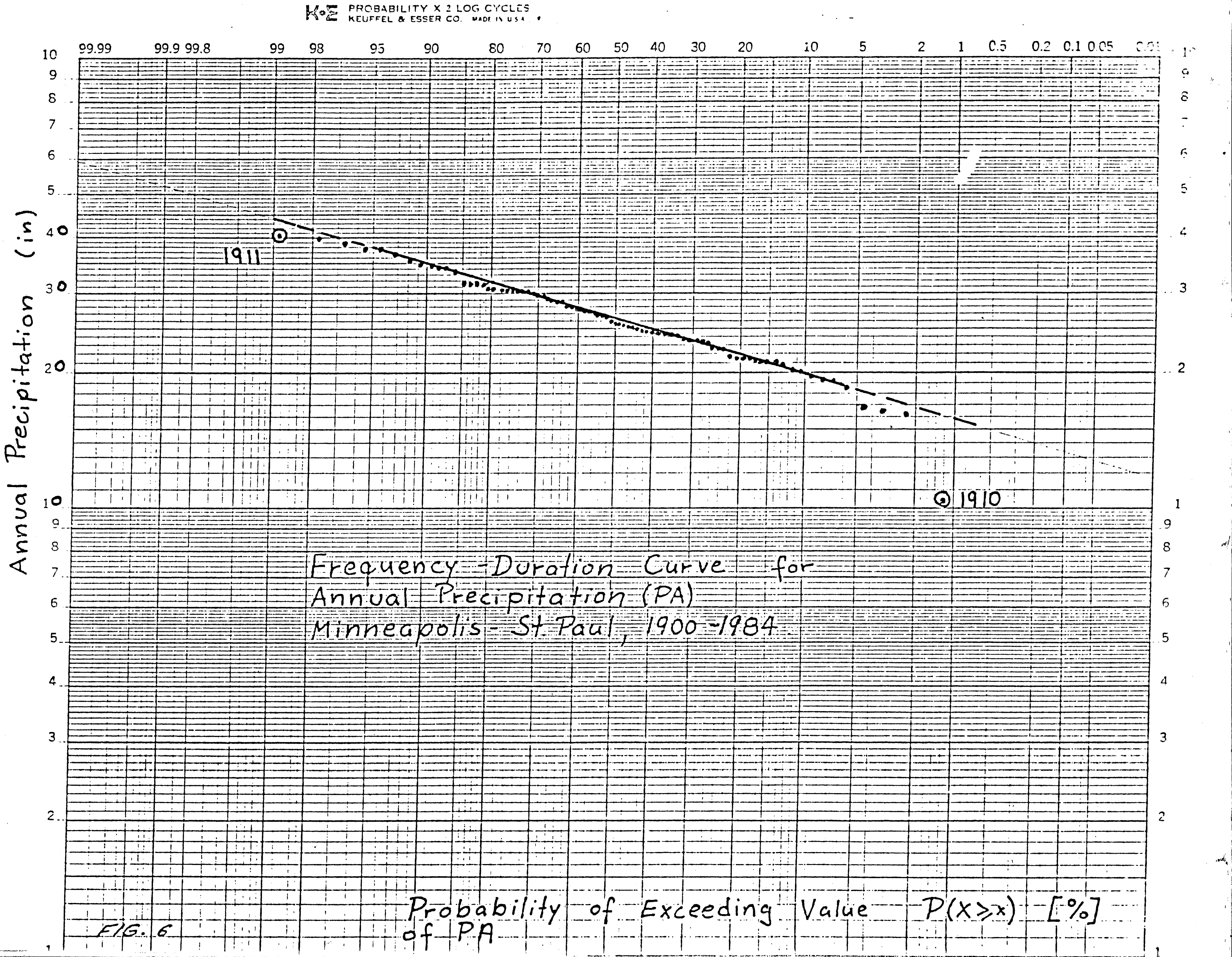

K+E PROBABILITY X 2 LOG CYCLES
KEUFFEL & ESSER CO. MADE IN U.S.A.
99.99 99.9 99.8 99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 0.5 0.2 0.1 0.05 0.01
Annual Precipitation (in)
40
30
20
10
1911
1910
Frequency - Duration Curve for
Annual Precipitation (PA)
Minneapolis - St. Paul, 1900 - 1984
Probability of Exceeding Value P(X≥x) [%]
of PA

FIG. 6

Weibull Frequency Formula.

$P\,(X \geq x) = \dfrac{m}{N+1}$

$T\,(X \geq x) = \dfrac{N+1}{m}$

N = 85
Period 1900–1984
PA = Annual Precipitation
P = Probability
T = Recurrence time.

m	1 Year	2 PA	3 P	m	Yr.	5 PA	6 P	m	Yr	8 PA	9 P
1	1911	40.44	1.16	32	81	27.97	37.21	63	07	23.07	73.26
2	1965	39.94	2.33	33	53	27.91	38.37	64	34	22.73	74.42
3	1983	39.04	3.49	34	57	27.85	39.53	65	43	22.71	75.58
4	68	37.93	4.65	35	35	27.50	40.70	66	31	22.60	76.74
5	03	37.88	5.81	36	26	27.34	41.85	67	80	21.77	77.91
6	84	36.84	6.98	37	45	27.20	43.02	68	50	21.61	79.07
7	75	35.15	8.14	38	41	27.00	44.19	69	37	21.49	80.23
8	77	34.88	9.30	39	59	26.88	45.35	70	60	21.46	81.40
9	51	34.60	10.47	40	56	26.75	46.51	71	12	21.16	82.56
10	00	34.22	11.63	41	27	26.43	47.67	72	73	21.13	83.72
11	04	34.11	12.79	42	64	25.97	48.84	73	55	21.11	84.88
12	06	33.21	13.95	43	01	25.75	50.00	74	47	21.09	86.05
13	09	31.82	15.12	44	61	25.74	51.16	75	25	20.87	87.21
14	02	31.75	16.28	45	67	25.44	52.33	76	23	20.25	88.37
15	08	31.60	17.44	46	49	25.14	53.49	77	30	20.05	89.53
16	79	31.07	18.60	47	22	25.05	54.65	78	63	19.57	90.70
17	15	30.79	19.77	48	17	24.93	55.81	79	69	19.29	91.86
18	05	30.76	20.93	49	21	24.82	56.98	80	74	19.11	93.02
19	24	30.57	22.09	50	28	24.80	58.14	81	36	18.47	94.19
20	42	30.56	23.26	51	20	24.70	59.30	82	48	16.75	95.35
21	19	30.38	24.42	52	14	24.62	60.47	83	76	16.50	96.57
22	78	30.26	25.58	53	16	24.51	61.63	84	58	16.20	97.67
23	82	30.23	26.74	54	39	24.50	62.79	85	10	10.21	98.84
24	18	30.19	27.91	55	29	24.39	63.95				
25	70	29.80	29.07	56	66	24.34	65.12			PAVE $\bar{x}$	26.61
26	38	29.75	30.23	57	13	24.05	66.28			$\bar{s}$	5.78
27	71	29.44	31.40	58	72	23.77	67.44			$\bar{x}+\bar{s}$	32.39
28	44	29.08	32.56	59	54	23.68	68.60			$\bar{x}-\bar{s}$	20.82
29	46	28.97	33.72	60	58	23.67	69.77				
30	62	28.83	34.88	61	32	23.56	70.93				
31	40	28.54	36.05	62	33	23.52	72.09				

NEGB-STMAUL SPECIAL ,MM MONTHLY PRECIPITATION

####	YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	ANN
%15435	1836	m	m	m	m	m	m	728	555	455	55	[illegible]	[illegible]	m
%15435	1837	27	35	35	95	265	346	273	132	510	315	137	234	2402
%15435	1838	65	76	15	241	305	476	1110	308	71	16	47	45	2771
%15435	1839	131	36	71	271	328	180	350	104	161	211	166	107	2119
%15435	1840	49	49	65	155	231	350	289	340	233	231	322	13	2317
%15435	1841	24	21	143	140	150	424	157	117	610	155	84	142	2167
%15435	1842	95	72	44	217	168	373	178	481	483	0	346	60	2517
%15435	1843	115	146	82	75	312	522	209	184	514	50	143	27	2379
%15435	1844	150	72	97	515	450	164	480	437	425	97	77	38	3024
%15435	1845	49	140	290	315	151	680	256	328	221	66	40	9	2534
%15435	1846	52	3	171	290	200	310	495	380	233	245	210	21	2610
%15435	1847	29	11	44	45	496	266	366	249	400	37	171	66	2190
%15435	1848	62	113	171	19	573	283	460	319	246	65	10	40	2318
%15435	1849	10	1	66	357	502	329	444	654	277	535	140	155	3510
%15435	1850	167	83	223	260	57	462	615	277	182	32	168	4	2550
%15435	1851	20	13	123	268	396	215	260	329	361	118	231	5	2339
%15435	1852	6	14	204	249	472	8	274	89	72	82	22	15	1507
%15435	1853	0	1	2	73	408	759	165	257	214	1	56	111	2047
%15435	1854	72	3	103	251	430	331	392	175	655	123	60	64	2659
%15435	1855	167	41	187	29	123	238	132	441	626	90	238	167	2478
%15435	1856	89	18	22	447	162	76	247	109	324	397	170	201	2262
%15435	1857	348	94	79	425	205	675	65	203	246	0	575	255	3209
%15435	1858	87	73	122	379	341	394	316	284	295	147	120	93	2653
%15435	1859	60	50	333	170	495	549	295	272	395	46	201	75	2941
%15435	1860	14	115	104	292	605	474	176	88	422	464	52	41	2927
%15435	1861	55	194	15	250	636	496	269	297	256	280	254	10	3012
%15435	1862	167	59	163	267	135	265	714	457	239	106	59	137	2818
%15435	~~1863~~	~~112~~	93	197	80	287	2	63	317	123	144	29	130	1577
%15435	1864	38	0	128	110	47	162	414	200	114	160	109	71	1553
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%15435	1866	190	32	132	201	39	598	230	473	226	264	319	50	2754
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%15435	1868	170	151	122	131	376	268	407	308	288	456	368	58	3103
%15435	1869	42	283	96	56	234	220	167	766	1061	88	75	93	3181
%15435	1870	118	62	210	139	524	79	313	856	328	195	133	90	3047
%15435	1871	161	41	206	425	270	656	148	487	218	190	141	120	3063
%15435	1872	28	26	164	169	571	381	423	352	562	52	191	63	2982
%15435	1873	131	154	134	244	463	774	383	461	256	257	79	38	3374
%15435	1874	49	107	224	95	165	1167	194	390	576	321	190	72	3550
%15435	1875	141	172	219	227	306	433	82	874	216	156	84	156	3066
%15435	1876	73	66	143	223	315	202	273	528	299	127	93	25	2367
%15435	1877	55	1	157	192	543	713	52	283	256	362	124	142	2880
%15435	1878	100	67	124	243	233	358	447	143	213	185	61	104	2278
%15435	1879	11	112	97	45	718	176	932	278	226	256	141	247	3239
%15435	1880	81	97	230	158	263	555	275	363	174	218	293	269	[illegible]
%15435	1881	434	265	106	47	434	287	260	455	995	444	136	53	[illegible] MX
%15435	1882	67	235	325	161	244	268	284	245	27	199	161	98	2314
%15435	1883	64	44	6	492	212	704	433	122	223	110	101	159	2670
%15435	1884	48	127	134	200	209	357	293	299	448	243	65	198	2611
%15435	1885	30	20	55	319	212	373	506	369	352	93	69	84	2533
%15435	1886	176	25	109	367	82	363	144	227	369	72	207	148	2289
%15435	1887	179	89	33	314	160	289	389	337	435	148	65	147	2585
%15435	1888	72	64	111	514	475	195	555	223	170	110	34	63	2566
%15435	1889	55	31	99	114	286	161	308	356	51	6	97	132	1696
%15435	1890	95	50	111	180	366	529	187	220	273	279	38	10	2338
%15435	1891	101	118	94	171	133	408	207	342	58	157	103	227	2179
%15435	1892	2	144	75	97	517	750	504	366	172	139	36	53	3255
%15435	1893	73	187	196	530	266	200	168	240	270	149	81	235	2595
%15435	1894	104	10	328	470	663	151	13	36	182	449	61	153	2590
%15435	1895	105	42	95	209	289	418	412	259	475	9	85	38	2426
%15435	1896	81	17	293	563	467	330	112	448	245	339	507	71	3473
%15435	1897	213	103	295	156	161	818	635	219	137	187	93	70	3052
%15435	1898	4	169	196	122	340	271	194	390	90	591	159	15	2534
%15435	1899	87	93	287	135	350	723	151	280	121	309	81	130	[illegible]

Table (6.6)

Table (6.6) cont.

%15435	1900	65	73	148	180	34	[illegible]	[illegible]	[illegible]	939	[illegible]	[illegible]	[illegible]	[illegible]
%15435	1901	37	40	252	114	164	721	730	208	504	91	160	54	2575
%15435	1902	53	68	58	304	392	249	550	564	316	133	240	248	3175
%15435	1903	27	62	233	346	528	116	561	490	784	541	35	65	3788
%15435	1904	41	76	147	174	320	499	573	541	450	505	12	73	3411
%15435	1905	75	39	102	30	413	624	271	607	415	249	247	4	3076
%15435	1906	120	22	107	223	1040	455	257	183	471	191	173	79	3321
%15435	1907	81	83	53	132	127	453	470	407	248	96	108	49	2307
%15435	1908	52	87	116	423	757	514	294	107	396	219	67	128	3169
%15435	1909	156	218	49	242	337	441	366	289	406	260	264	152	[illegible]
%15435	1910	110	42	16	59	176	91	99	58	177	75	48	30	[illegible]
%15435	1911	73	87	74	222	399	579	515	550	527	755	112	151	4042
%15435	1912	52	7	32	260	406	110	402	440	127	118	8	154	2116
%15435	1913	33	71	174	162	295	305	611	159	334	203	56	2	2405
%15435	1914	105	49	93	373	148	649	95	448	216	188	48	50	2462
%15435	1915	119	221	99	275	388	358	453	398	292	159	264	53	3079
%15435	1916	260	39	126	303	599	379	75	160	121	126	92	121	2451
%15435	1917	179	44	209	165	392	379	412	282	200	169	6	57	2477
%15435	1918	51	69	88	94	452	281	505	519	149	261	345	205	3013
%15435	1919	44	252	81	398	213	440	747	222	125	191	257	66	3039
%15435	1920	180	57	291	221	197	776	135	96	136	185	108	88	2479
%15435	1921	59	46	251	246	338	470	239	279	321	48	158	27	2482
%15435	1922	90	369	141	155	248	461	232	131	183	108	370	18	2505
%15435	1923	112	50	133	220	228	428	251	192	110	200	35	66	2025
%15435	1924	97	58	283	332	147	724	173	651	305	76	75	136	3057
%15435	1925	58	62	39	127	228	577	428	16	349	83	59	61	2087
%15435	1926	97	54	146	53	137	365	292	427	543	235	212	173	2734
%15435	1927	68	28	207	216	259	398	211	195	427	225	147	262	2643
%15435	1928	31	163	80	245	216	260	363	610	204	246	21	41	2480
%15435	1929	152	95	129	243	197	466	371	137	336	245	32	34	2437
%15435	1930	100	209	59	75	335	444	100	48	290	150	172	17	2005
%15435	1931	13	72	156	147	108	407	154	345	256	231	294	77	2260
%15435	1932	194	96	145	239	211	220	386	276	72	108	229	180	2335
%15435	1933	128	87	215	132	775	92	216	109	344	126	57	71	2352
%15435	1934	67	17	68	157	21	230	140	161	486	564	238	123	2273
%15435	1935	144	21	163	232	381	462	259	302	198	395	69	104	2750
%15435	1936	77	155	266	149	225	229	11	348	78	66	66	178	1847
%15435	1937	124	77	87	234	502	186	117	423	209	123	24	43	2149
%15435	1938	87	62	211	327	697	296	336	345	324	84	129	77	2975
%15435	1939	106	88	61	219	355	495	275	365	231	156	2	97	2450
%15435	1940	37	91	216	121	164	710	246	454	41	157	515	102	2854
%15435	1941	74	89	77	187	291	329	198	366	347	552	105	85	2700
%15435	1942	15	45	174	341	678	269	380	211	753	78	27	85	3056
%15435	1943	91	57	81	98	427	423	378	175	247	130	164	0	2271
%15435	1944	24	110	120	224	615	669	439	365	97	26	210	9	2908
%15435	1945	63	184	195	295	309	557	413	227	213	30	93	141	2720
%15435	1946	94	115	120	66	304	780	276	43	658	251	122	68	2897
%15435	1947	71	20	47	244	257	530	96	241	148	110	285	60	2109
%15435	1948	15	137	143	177	74	258	134	337	104	60	189	67	1695
%15435	1949	165	14	337	189	90	274	601	264	267	172	42	99	2514
%15435	1950	127	63	220	219	287	126	374	184	146	122	09	199	2161
%15435	1951	44	171	300	186	414	550	544	194	580	144	212	121	3460
%15435	1952	105	120	309	59	286	398	456	418	42	1	128	45	2367
%15435	1953	55	123	151	204	192	710	681	275	55	15	154	176	2791
%15435	1954	25	32	210	353	254	471	133	308	365	123	61	33	2368

Table (6.6) cont.

%15435	1955	47	154	52	92	69	153	710	234	99	221	104	126	2111
%15435	1956	48	20	162	67	257	658	532	522	79	193	135	20	2675
%15435	1957	32	83	131	123	313	413	631	575	165	140	156	24	2785
%15435	1958	21	24	32	199	139	201	315	303	109	155	101	21	1620
%15435	1959	11	61	59	64	503	407	260	660	225	243	63	128	2083
%15435	1960	68	22	81	204	319	308	193	399	379	31	87	55	2146
%15435	1961	78	89	281	239	349	187	294	278	301	303	106	160	2574
%15435	1962	55	207	187	131	803	149	512	347	246	169	52	26	2897
%15435	1963	46	41	118	207	504	191	153	155	317	81	57	60	1827
%15435	1964	47	6	135	258	344	218	292	[illegible]	531	[illegible]	115	[illegible]	[illegible]
%15435	1965	47	159	475	352	786	401	469	404	450	50	198	133	[illegible]
%15435	1966	95	155	248	89	146	351	247	440	169	353	39	192	2474
%15435	1967	363	159	96	407	61	753	136	279	63	173	9	45	2544
%15435	1968	71	13	189	294	374	678	646	75	616	562	54	221	3793
%15435	1969	205	31	90	155	198	293	295	99	49	253	55	206	1929
%15435	1970	47	16	205	282	477	127	366	219	319	457	382	45	2966
%15435	1971	122	174	121	111	314	352	394	178	273	568	267	70	2944
%15435	1972	84	49	125	169	219	331	512	248	196	177	111	157	2377
%15435	1973	92	84	112	232	248	106	290	305	208	129	197	110	2113
%15435	1974	17	106	100	242	208	521	114	275	58	159	66	35	1911
%15435	1975	282	79	167	540	381	799	58	492	131	27	480	79	[illegible]
%15435	1976	87	59	283	80	113	386	245	139	142	49	16	51	[illegible]
%15435	1977	65	93	266	184	286	357	372	931	443	234	142	115	[illegible]
%15435	1978	38	24	79	363	379	709	318	577	247	19	194	88	3036
%15435	1979	109	139	255	66	455	478	234	704	220	316	98	33	3107
%15435	1980	94	67	112	83	229	552	230	326	348	66	26	24	2177
%15435	1981	30	214	71	217	218	442	409	473	146	269	216	92	2797
%15435	1982	245	43	209	162	499	144	92	380	150	345	327	427	[illegible]
%15435	1983	67	121	322	397	615	522	307	312	334	261	493	153	[illegible]
%15435	1984	88	164	147	386	229	795	303	515	265	548	20	224	3482
	1985	.87	.50	4.48	1.81	3.65	2.18	2.20	5.02	4.37	3.66			

Note: Values in hundredths of inches; 'm'=missing; 'e'=estimated .
'####' is the National Weather Service Coop Station Number

All data were supplied to this State Climatology Office by the National Climate Data Center, NOAA, Asheville, NC, 28801.
'Certified Data' can only be supplied by NCDC directly.

State Climatology Office, Minnesota Dept. Natural Resources - Waters
Earl Kuehnast and Jim Zandlo. 612-296-4214.

88.37	88.53	163.67	214.50	333.83	328.0	379.87	379.87	245.40	223.33	145.17	104.20	2719.2
81.83	62.15	96.71	122.41	185.72	166.1	193.85	193.85	144.72	159.23	129.34	85.44	668.90

This graph will be used to pick a number of years which represent different occurrence probabilities for precipitation and which can be used to demonstrate lake level fluctuations. The normal rainfall, based on a 30-year record, is approximately 27 inches.

A note of caution needs to be made. The spatial variability of rainfall can be great, therefore the assumption that the rainfall at the airport is exactly the same as at Columbia Park is not necessarily correct, but it is more tenable for long time averages such as annual values.

Evapotranspiration: Evapotranspiration is the transformation of liquid water into vapor. Therefore it constitutes a direct subtraction of the available water. Evaporation takes place directly from open water surfaces whereas transpiration is mediated by plants. Both however are dependent on climatic conditions. The simplest way of estimating potential evapotranspiration is by the Thornthwaite Method which only uses mean monthly temperature. Potential evapotranspiration occurs when water is available at all times, such as from a lake. It is equal or greater than actual evaporation.

The Thornthwaite equation for monthly values has the form

$$PE = 16(10t/I)^a \times C$$

where PE is the potential evapotranspiration in millimeters, t is the average monthly temperature, I is an annual heat index, a is an empirical exponent based on the heat indices, and C is a factor that corrects for latitude and available sunshine hours. The summation of the monthly values gives the annual evapotranspiration. For the 30-year normal the annual value for this region is about 25.3 inches.

Figure 7 shows the deviation from the annual average temperature between 1891 and 1930. Again it shows that for the crucial period of lake level decline in the early part of the century deviation was not great and if anything tended to be below normal. This would indicate less of a loss due to evaporation and therefore does not explain the rapid lake level decline.

Figure 8a represents a Thornthwaite diagram in which the monthly precipitation (P) and potential evapotranspiration (PET) are plotted as indicated. Where precipitation lies about the PET curve a moisture surplus exists, where the PET curve lies above the P curve a deficit occurs. To get an idea of the overall effect the cumulative curves are more instructive (Fig. 8b). It can be seen that for the 30-year normal values the cumulative precipitation curve does not cross the cumulative potential evapotranspiration curve until July, then a short period of moisture deficiency exists, and by the end of the year it evens out again.

On the basis of these calculations P is more or less balanced by PET. For different years, however there would be moisture deficits or surpluses. However, the 30-year normal is a good basis for long term planning operatives.

Runoff: Runoff (RO) is the portion of precipitation that is available for surface runoff and collection or for subsurface movement of water. The total amount of runoff generated from a watershed depends on the amount of precipitation, the area of the watershed (A_w) and other parameters that determine abstraction and losses such as PET.

This complicated relationship can be approximated by a simple formula:

$$RO = P \times A_w \times C$$

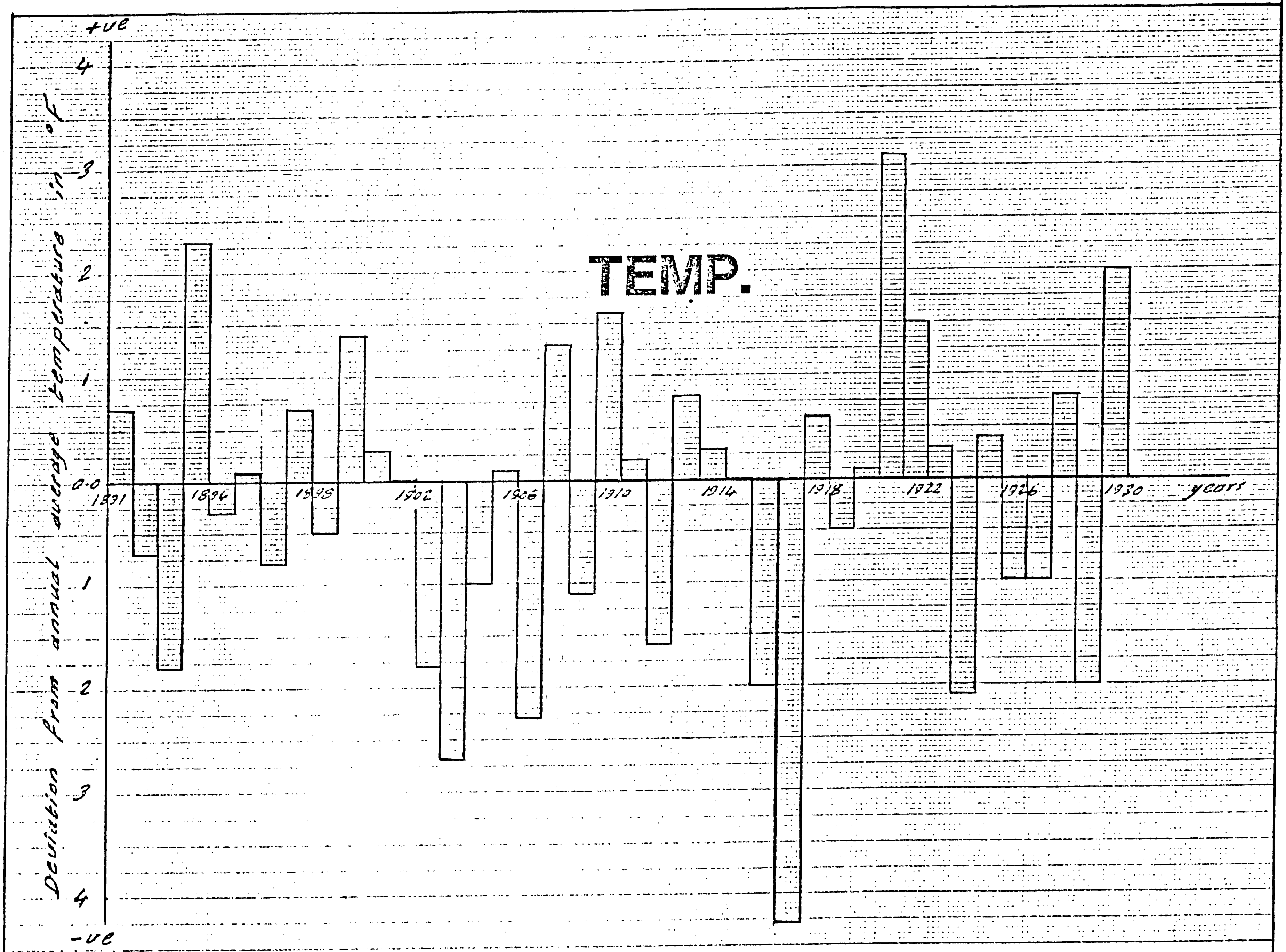

+ve
4
3
2
1
0.0
1
2
3
4
-ve
Deviation from annual average temperature in °F
TEMP.
1891
1894
1898
1902
1906
1910
1914
1918
1922
1926
1930
years

FIG. 7

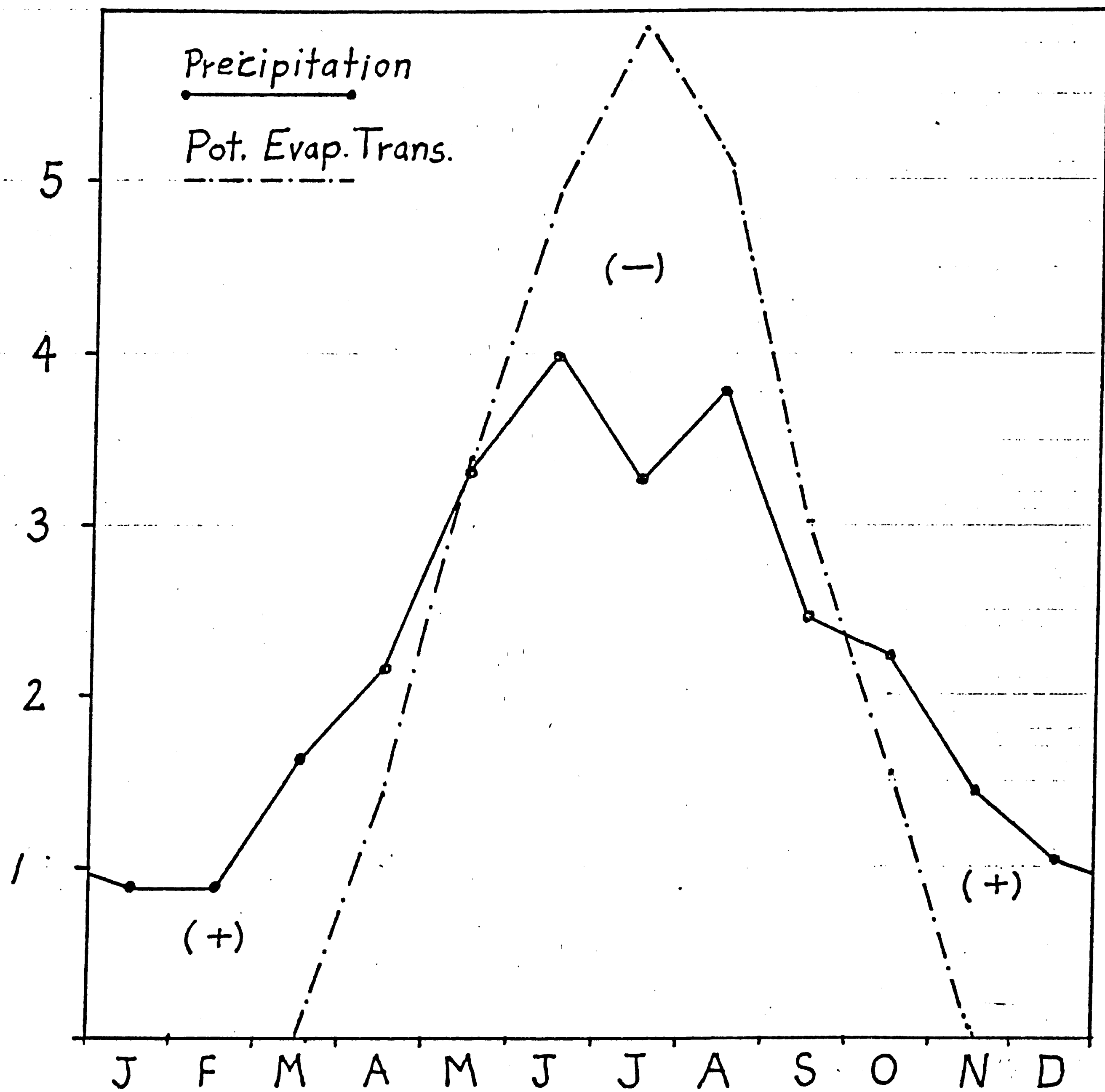


FIG. 8.a

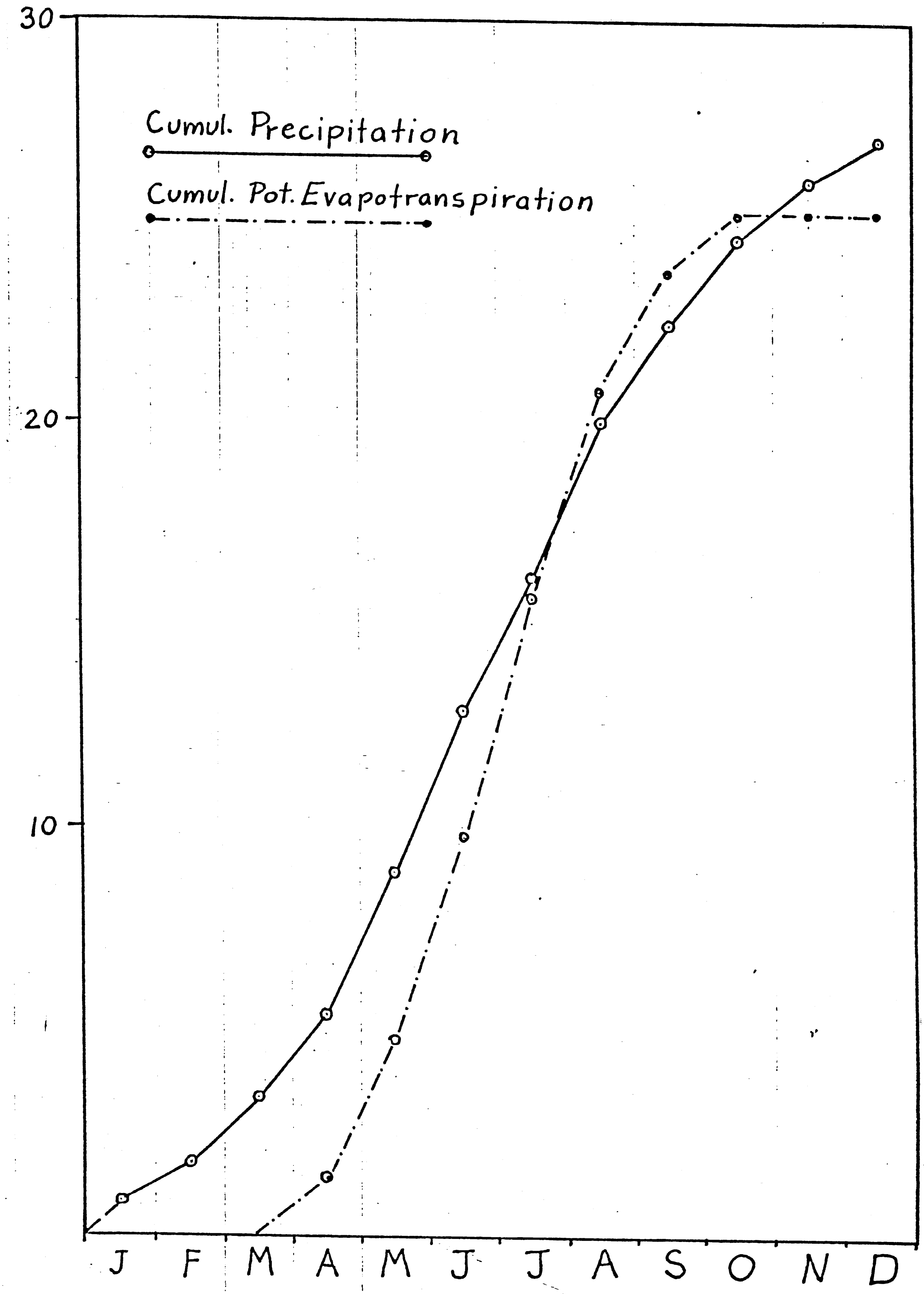

30
20
10
Cumul. Precipitation
Cumul. Pot. Evapotranspiration
J F M A M J J A S O N D

FIG. 8-6

30y. Normal. T. - 1955-1984. ST. PAUL

FIG. 8.c

		F T	T(°C)	PE in.
Jan	1	11.00	- 11.67	0
	2	17.33	- 8.15	0
	3	29.55	- 1.36	0
	4	45.86	7.70	1.42
	5	58.27	14.59	3.39
	6	67.80	19.89	4.91
	7	73.19	22.88	5.88
	8	70.98	21.66	5.01
	9	60.37	15.76	3.02
	10	49.45	9.69	1.54
	11	33.00	0.56	0.05
Dec	12	18.42	-7.54	0
	13	44.61	TE·Σi	25.30
	14	Blainey Criddle: (1953-1982)		
	15	Prairie Water Bal.:		

In.	P Cum. in	PE Cum in
.8837	.88	-0-
.8853	1.76	-0-
1.6367	3.40	-0-
2.1450	5.55	1.42
3.3383	8.89	4.81
3.9933	12.88	9.72
3.280	16.16	15.60
3.7987	19.96	20.69
2.4540	22.41	23.71
2.2333	24.64	25.25
1.4517	26.09	25.30
1.0420	27.13	
27.1420		

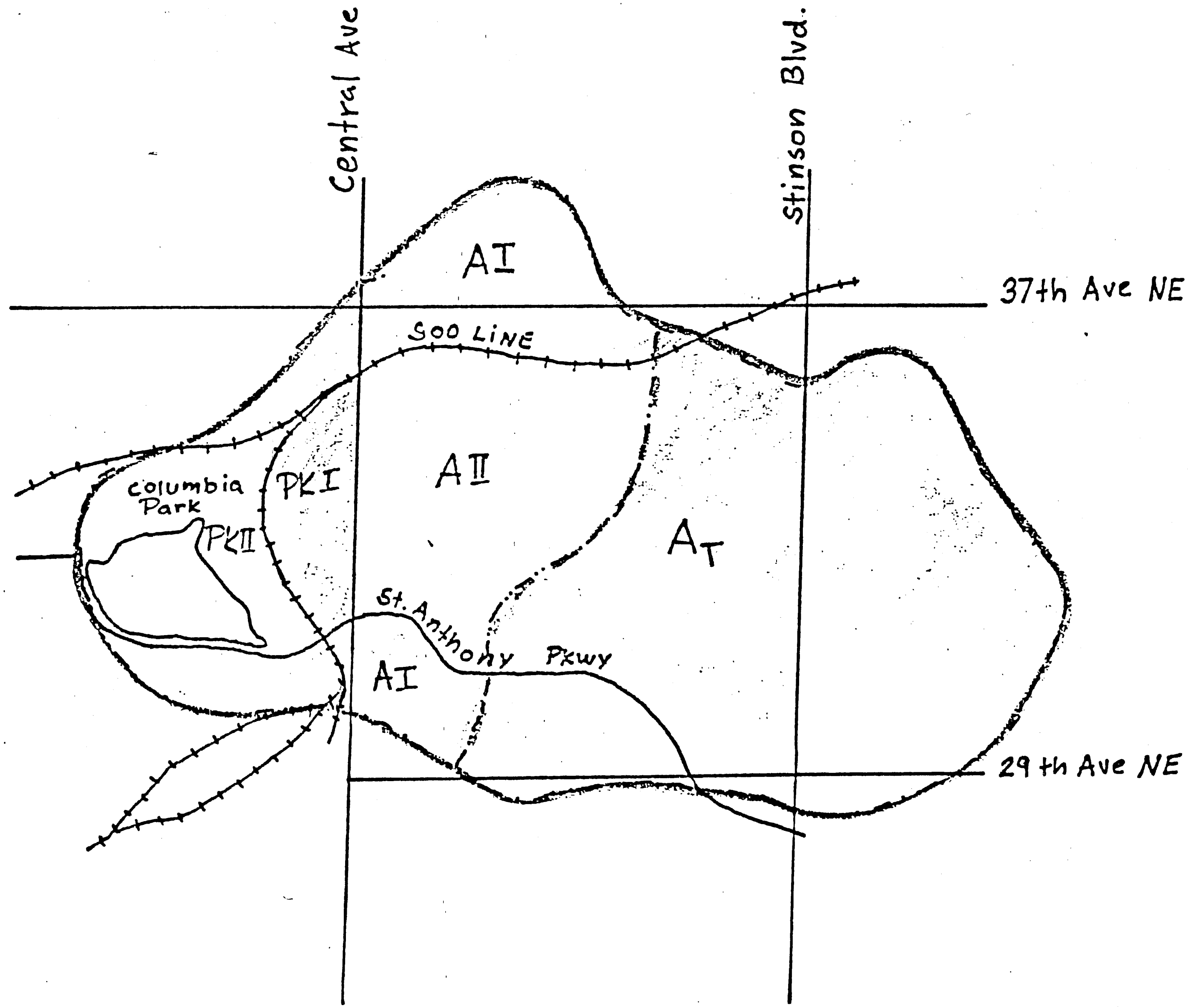
EFFICIENCY LINE • 22-206

where C is a runoff coefficient which may vary between very low values of 0.1 or less for flat and well drained areas to 0.7 to 0.8 for highly urbanized (impermeabilized) areas.

The contributing watershed areas have been determined by drawing the divide on a $7\frac{1}{2}$ minute topographic map. The different areas are shown in Figure 9. The larger catchment area (A_T) given by the area within the entire perimeter is undoubtedly not applicable for runoff calculations since much of it is sewered for storm runoff and runoff therefore will be carried away by storm sewers. The storm sewer system is shown in Figure 10.

The different areas are defined and their acreage given on Figure 9b. These will be used for runoff calculations in the lake water balance.

Groundwater Runoff: This is the subsurface portion of runoff. It is much more difficult to evaluate because water table elevations and contour lines have to be established through well observations. From these flow direction and head gradients can be established. With some knowledge of the hydraulic conductivity of the aquifer materials, flow discharges can be estimated. For more sophisticated treatments groundwater simulation models can be used to more accurately calculate discharge and its distribution in the aquifer. For this study this type of information was not available. However, general trends of equipotential lines will be north-south and groundwater flow will be from east to west, ultimately discharging into the river. Due to the somewhat irregular topography and the relief in the park, local flow systems are bound to exist. They may cause focussing of groundwater flowlines into the depressions.



Central Ave
Stinson Blvd.
AI
37th Ave NE
SOO LINE
AII
Columbia Park
PKI
PKII
AT
St. Anthony Pkwy
AI
29 th Ave NE

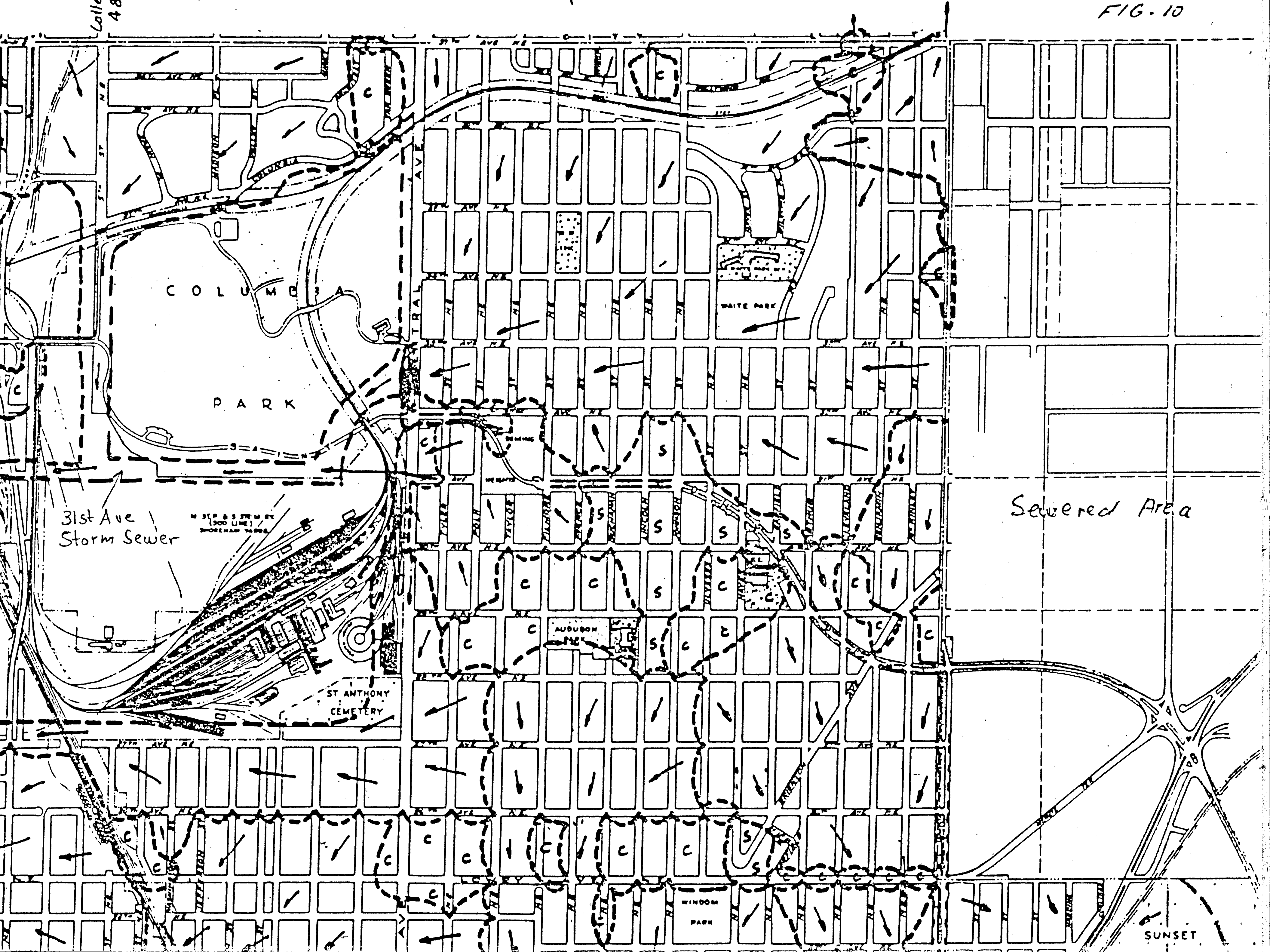
FIG. 9.a

SYMBOL	AREA DESCRIPTION	Acreage
PK II	: Area between St.Anthony Pkwy to So + W, Soo Line to No + E	120
PK I	: PK II + Area E of Soo Line W of Central Ave, No of St. Anthony Pkwy	175
A II	: PKI + Area contained between Central Ave, St.Anthony Pkwy, Soo Line, and dashed line (approx N-S) indicated	400
AI	: AII + Areas indicated as AI So of St Anthony Pkwy and No of Soo Line	640
AT	: AI + Area to East of dashed line (N-S) marked as AT - Total Area within divide	1310

Figure 9.6 Watershed Areas

Storm Sewers NE Minneapolis

FIG. 10



Lake Hydrology

Morphometric Characteristics

Besides its setting in the general hydrogeologic environment, it is important to establish lake morphometric characteristics that will give some indication about the lake's hydrology and expected behavior under different climatic regimes. These will also influence the limnologic behavior of the lake system.

Lake surface area, depth and volume are the fundamental parameters. Figure 11 shows the topographic contour lines of the old lake basin. Assuming that it can be filled each one of these would indicate a lake level stage with an associated lake surface area. The areas related to each contour line, or contained within one closed contour line, were determined by planimetry on topographic maps with 2 ft intervals (Mark Hurd Aerial Survey). The cumulative lake volume and the area are shown as a function of deviation of the contour lines (Fig. 12). The determinations have been carried out for the basin north of St. Anthony Parkway and for the depression south of it. Mean lake depth ($\bar{z}$) vs. elevation (Fig. 13) indicate that the north basin has a $\bar{z}$ of nearly 8 ft, the south basin of 6 ft, if they are filled to the 840 contour. Any higher filling could cause flooding and damage to existing structures. Figure 14 shows the lake and 14a gives an overview over the morphometric parameters their definitions and formulas. Table 14a is for an assumed lake elevation of 838 ft NGVD.

According to this both basins are relatively shallow, approximately the same mean depth as Lake of the Isles in Minneapolis. Table 14b summarizes the hyp-sographic relationships for all elevations.

The two factors of importance to lake restoration are the value over 11 million cf, and the lake level fluctuations. The first gives an indication of


COLUMBIA BLVD
5TH ST NE
CENTRAL AVENUE
0
500'
Scale
500 RR
840
832
830
828
834
836
838
826
828
830
832
834
836
838
840
ST ANTHONY PKWY
832
834
836
838
840
500 RR

FIG. 11

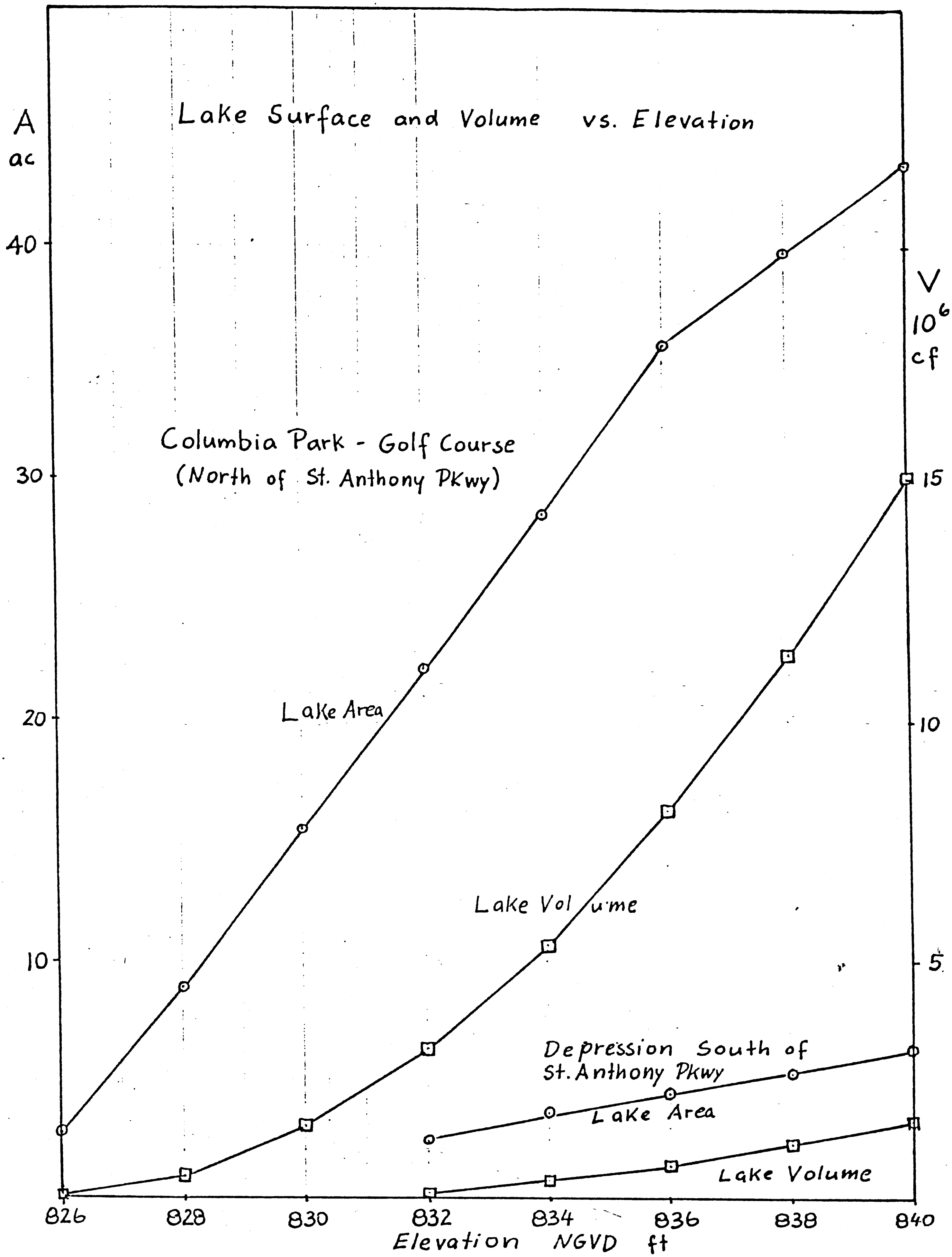
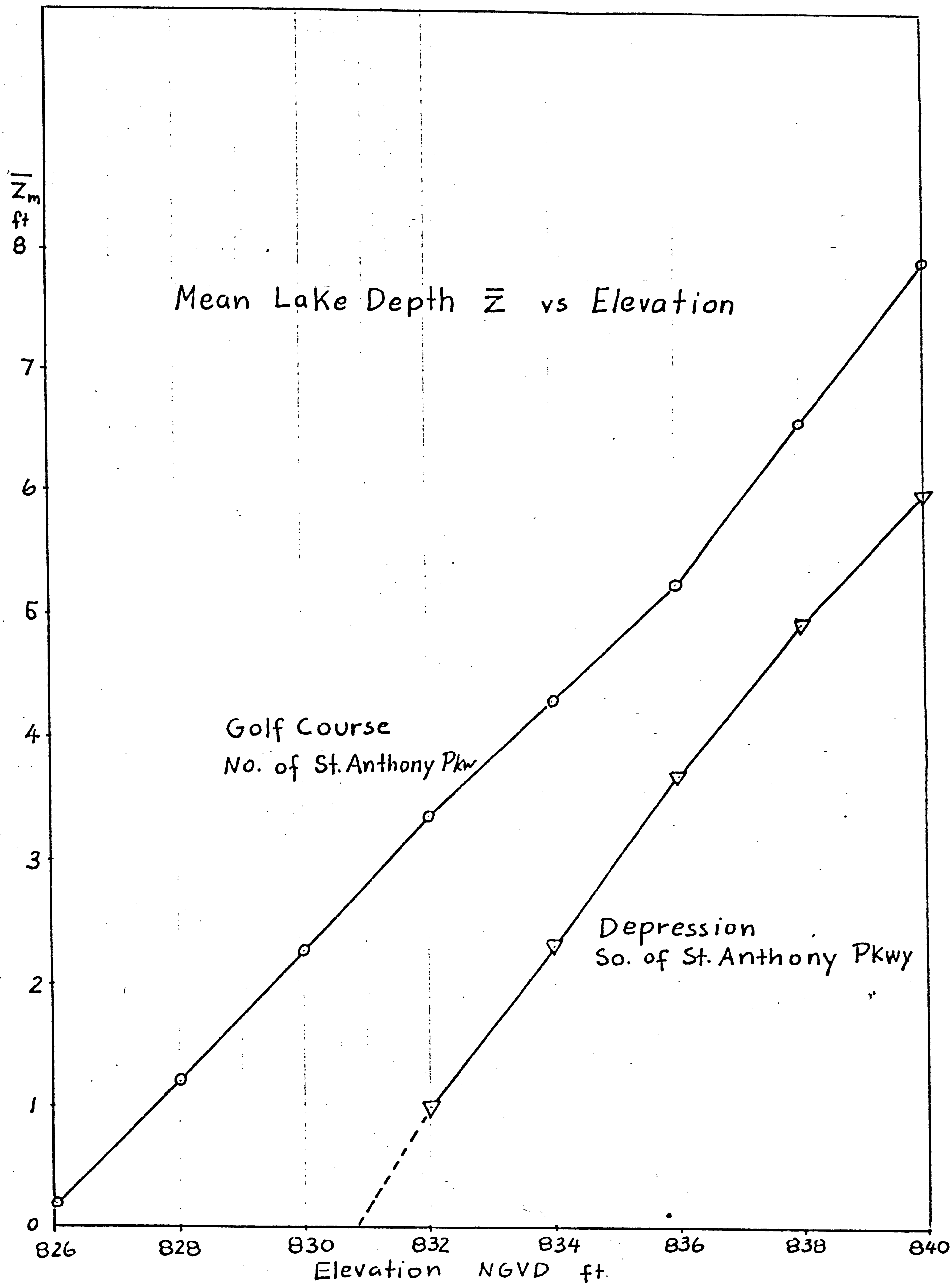

Lake Surface and Volume vs. Elevation
A
ac
V
10^6
cf
Columbia Park - Golf Course
(North of St. Anthony Pkwy)
Lake Area
Lake Volume
Depression South of
St. Anthony Pkwy
Lake Area
Lake Volume
40
30
20
10
15
10
5
826
828
830
832
834
836
838
840
Elevation NGVD ft

FIG. 12



Mean Lake Depth $\bar{Z}$ vs Elevation
$\bar{Z}_m$ ft
0
1
2
3
4
5
6
7
8
826
828
830
832
834
836
838
840
Elevation NGVD ft.
Golf Course
No. of St. Anthony Pkw
Depression
So. of St. Anthony Pkwy

FIG. 13

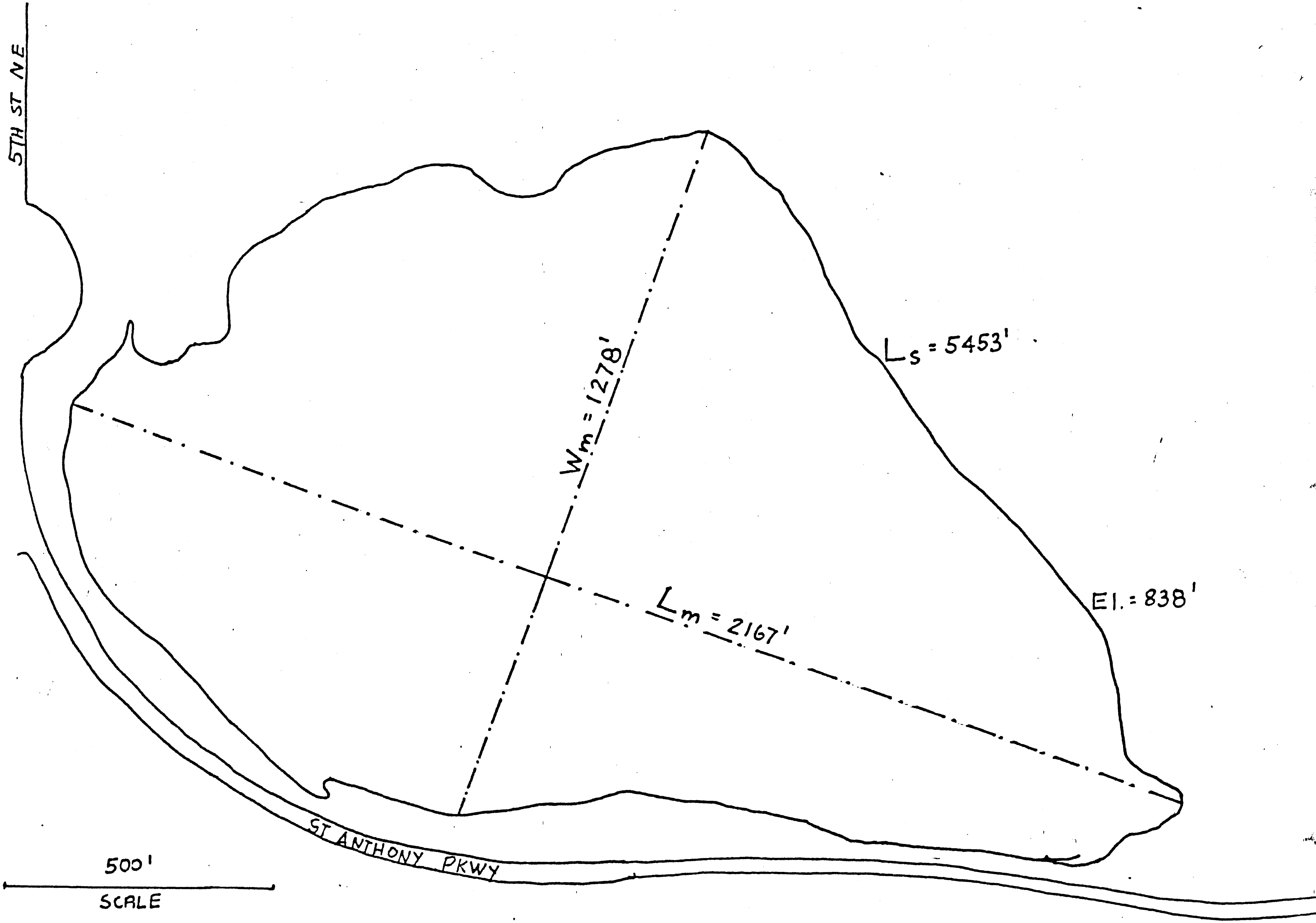

5TH ST NE
$L_s = 5453'$
$W_m = 1278'$
$L_m = 2167'$
El. = 838'
ST ANTHONY PKWY
500'
SCALE

FIG. 14

MORPHO METRIC PARAMETERS			
Area of Lake	A	(39.8 ac)	$1.73 \times 10^6 ft^2$
Elevation of Lake Surface		NGVD	838 ft
Maximum Length:	L_m		2167 ft
Maximum Width:	W_m		1278 ft
Lake Volume:	$V = \frac{h}{3}(A_1 + A_2 + \sqrt{A_1 \cdot A_2})$		11.4×10^6 cf
Maximum Depth:	Z_m		12.4 ft
Mean Depth:	$\bar{Z} = V/A$		6.59 ft
Development of Volume:	$D_V = 3\bar{Z}/Z_m$		1.59
Shoreline:	L		5453 ft
Development of Shoreline	$D_L = \frac{L}{2\sqrt{\pi A}}$		1.16
	$\bar{Z}/Z_m$		0.53

FIG. 14-a

Hypsography

Basin North of St. Anthony Pkwy

El.	h	A_c	$\Delta V_{A_1A_2}$	ΣV	z_m	$\bar{z}$	A	$\bar{z}/z_m$	$D_v = \frac{3\bar{z}}{z_m}$
(ft)	(ft)	(ft²)	(ft³)	(ft³)	(ft)	(ft)	(ac.)		
825.6	0			0	0	0			
826	0.2*	120 881	24,176	24 172	0.4	0.2	2.78	0.50	1.50
828 (a)	0.6*	160 329	96,197	462,163	2.4	1.20	8.88	0.50	1.50
(b)	2.0	226 385	341,794						
830	2.0	674 476	1,047,936	1,510,099	4.4	2.24	15.48	0.51	1.53
832	2.0	965 804	1,631,587	3,141,686	6.4	3.25	22.17	0.51	1.52
834	2.0	1 240 907	2,200,972	5,342,658	8.4	4.31	28.49	0.51	1.54
836	2.0	1 552 204	2,787,310	8,129,968	10.4	5,24	35.63	0.50	1.51
838	2.0	1 733 256	3,283,796	11,413,764	12.4	6.59	39.79	0.53	1.59
840	2.0	1 897 197	3,629,219	15,042,983	14.4	7.93	43.55	0.55	1.65

Basin South of St. Anthony Pkwy.

El.	h	A_c	ΔV	ΣV	$\bar{z}$	z_m	A	$\bar{z}/z_m$	D_v
830.8	0			0	0	0			
832	1.0	104 479	104,479	104,479	1.0	1.0	2.40	1.0	3.0
834	2.0	157 609	260,274	364,753	2.31	3.0	3.62	0.77	2.3
836	2.0	193 268	350,271	715,024	3.70	5.0	4.44	0.74	2.2
838	2.0	231 065	423,770	1,138,794	4.93	7.0	5.30	0.70	2.11
840	2.0	274 212	504,662	1,643,456	5.99	9.0	6.30	0.67	2.0

the volumes of water needed to fill the lake, the second is important in lake management practices and can be evaluated from lake balance calculations.

Lake Water Balance

The most representative lake level elevation is chosen as the basis for the balance calculations. This is elevation 838, for which the values on Figure 14a are valid.

A balance equation is set up in terms of the lake level change C:

$$C = P - PET + SRO \pm GWRO$$

where SRO is the surface water runoff directly into the lake from the surrounding contributing watershed area. For an enclosed lake without inlet and outlet channels it is always positive, GWRO is the net amount of groundwater seepage contribution to the lake, it can be positive or negative depending on whether inseepage is larger or smaller than outseepage. The term is the result of a difference which could be the same for two large absolute inseepage-outseepage volumes or between two small absolute inseepage-outseepage contributions. From a lake level management point of view, it is the difference that counts, but for limnological purposes the absolute throughflow is important because it determines the renewal or replacement time for a lake volume. The smaller this time is, the more often the lake volume is replaced and the less stagnant a water body becomes.

For the potential lake at the 838 elevation the following assumptions are made:

- As a worst case, a net outseepage of groundwater is taken. Outseepage for small shallow lakes have been determined by Allred et al. (1968,

1970) to average 0.0033 ft per day or 1.2 ft per year for representative lakes in the metropolitan area. Other studies of the Minneapolis Chain of Lakes (Ferguson 1980, E.A. Hickok 1984) show a wider range of values but they also average out to be of the same order of magnitude. Therefore 0.0033 is adopted as a reasonable first approximation. It needs to be pointed out that actual seepage amounts depend on the configuration of the groundwater flowfield around the lake, mainly the position of the water table, the relative position of the lake level with respect to the water table, and the permeability conditions of the lake sediments and surrounding aquifer. The seepage term may therefore vary in direction and magnitude throughout a water year. Assuming a perennial outseepage from the potential lake is therefore a worst case scenario. Based on the observation of permanent wet-spots and standing water in the center of the depression a slight inseepage to the lake may be more realistic.

- It is impractical to measure the surface runoff term, SRO, directly, therefore an empirical runoff factor CF is applied to the precipitation that falls over the contributing watershed.

$$SRO = A \cdot CF$$

Values for CF vary widely, for very permeable, flat and well drained areas CF may be less than 0.1, for impermeabilized and paved urban areas it may be as high as 0.8. For this particular study a conservative value of CF = 0.2 was chosen. This is in line with values that have been observed in similar settings around the Minneapolis Chain of Lakes

(E.A. Hickok 1982, Olson and Pfannkuch 1980). It is conservative because for the type of terrane surrounding the lake a large portion of the infiltration that does not run off from the surface may reappear as interflow at the bottom of hills and at margins of depressions. The hilly portions east and northeast of the depression are made up of fairly sandy and permeable materials, which favor infiltration. The steep slopes on the other hand and the heterogeneity of the subsurface favor interflow, which would be focussed and directed toward the depression.

The balance was written with the 30-year normal monthly precipitation P(ft), potential evapotranspiration as determined by the Thornthwaite equation based on 30-year normal monthly temperatures, PET(ft). Note that the months with subfreezing average temperatures do not contribute to PET. Some evaporation does, however, occur during this time, therefore annual PET would be underestimated. On the other hand monthly PET values for months in the pre- and post-growing seasons are overestimated by the Thornthwaite method, and it is assumed that the two compensate each other.

Groundwater outseepage is calculated according to the fixed daily rate of 0.0033 ft and multiplied by the appropriate number of days in the month to yield monthly values.

The surface runoff is calculated on the basis of monthly precipitation, the coefficient CF = 0.2, the different contributing areas PI, PII and AII. To go any further in use of areas AII and AT seems unrealistic in view of the urbanization and modification of the topography as well as the extensive storm sewer system installed, as discussed earlier.

Lake level changes (C1, C2, C3) are calculated on a monthly basis considering the contributions from the three possible watershed areas respectively. These three cases are plotted on Figure 15 on a monthly basis starting from a hypothetical zero at the beginning of the normal year. Cumulative stage curves are also shown on the same figure, they indicate what the cumulative effect of the contributions would be with time.

From Figure 15a it can be seen that for 30-year normal conditions a small deficit of 0.15 ft is accrued for the case that contributing runoff is generated from area PI only where the landed watershed to lake ratio is relatively small at 2.0. This level deficit translates to a volumetric deficit of 1.95 million gal. If one were to consider supplementing lake water by pumping deep groundwater (from the Shakopee formation for example) a 500 GPM capacity pump would have to run only 65 hours a year. The balance calculation hinges on the assumed seepage loss, if it is less, or positive as inseepage, no deficits would occur. This is the case for the balance involving area PII, and especially area AII, even with assumed losses to the groundwater reservoir. In both these cases the lake level management problem may be to get rid of excess water.

Obviously the 30-year normal climatic conditions are only a statistical concept, therefore a number of representative years have been selected for further analysis. The greatest variability in annual and monthly data is in precipitation, whereas temperature conditions, which control the PET values, are much less variable. Precipitation is therefore considered the most important parameter in the balance. From the precipitation-duration curve a number of yearly data were selected on the basis of the probability that any year's precipitation will exceed the precipitation of the reference year. Low precipitation (less than 50%) represent wet years, high percentages (> 50%) represent dry years. 1963 was chosen as a dry year (91%) and 1984 as a reasonably wet year (7%). The years 1980 to 1982 cover a range of intermediate values and are fairly recent data. The characteristics P, probability and recurrence interval are shown on Table 6a, monthly balance calculations are given in Figure 8c and a plot of monthly lake level changes is given on Figure 15. As can be seen lake level changes in actual years can be quite significantly different from the normal year, with annual and seasonal fluctuations in the order of 0.5 ft.

If one assumes a lake level drop of 1 ft as acceptable then the shoreline area exposed at the lowest level (837 ft) is 155000 ft^2 corresponding to a strip of about 28 exposed feet around the lake on the average. Under this assumption supplementation would have been necessary in the dry year 1968 and possibly in 1980 if only the smallest watershed area (PKII) were contributing runoff. These are examples of isolated years only and over a certain period yearly deficit accumulations may have to be compensated for. But in all cases this would on the average be of the same order as for the normal year values discussed above.

From the calculations and the figures it also becomes apparent that the more general operational problem would be to control excess lake levels, especially if the larger watershed areas (PKI and AII) are contributing.

The above discussion indicates that under the assumed conditions of groundwater seepage, runoff would sustain a lake in parts of the old Lake Sandy lake bed north of St. Anthony Parkway, once the lake basin has been filled.

The southern portion of the old lake basin cut off by the Parkway and partially filled to the south by the railroad has a watershed defined by St. Anthony Parkway and the service road to the south. Its area is about 20 acres

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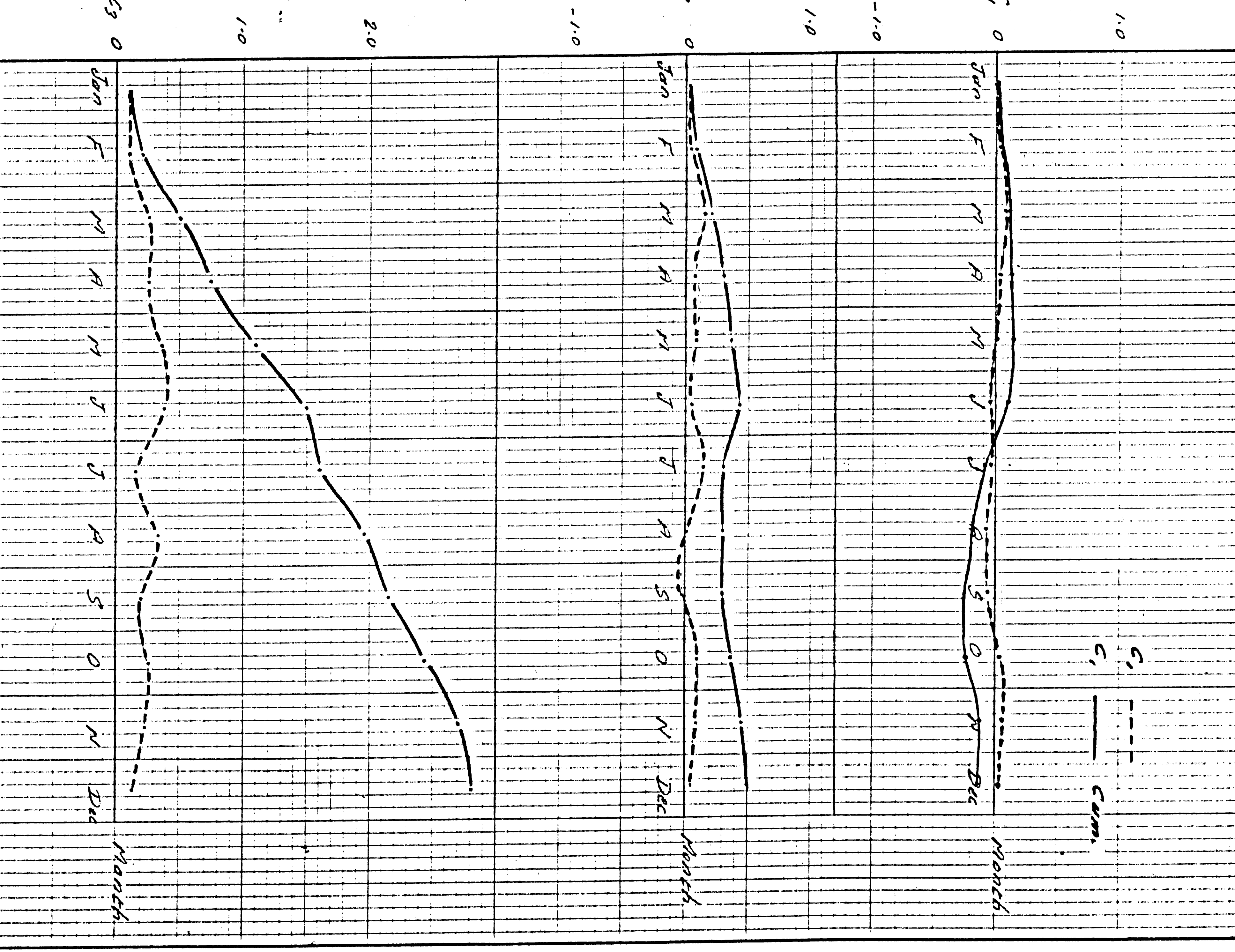


FIG. 15-a

Lake Level Changes. - $C = P - PE - GW + RO$

	1 P	2 PE	3 GW	4	5 RO 1	6 RO 2	7 RO 3	8 C1	9 C2	C3
J	0.0736	- 0 -	0.1023		0.0294	.0497	.1251	0.0007	0.0210	0.096
	0.0738	- 0 -	0.0924		0.0295	.0498	.1255	0.0109	0.0312	0.106
	0.1364	- 0 -	0.1023		0.0546	0.0921	.2319	0.0887	0.1548	0.266
	0.1788	0.1183	0.0990		0.0715	0.1207	.3040	0.0330	0.0822	0.265
	0.2782	0.2825	0.1023		.1113	0.1878	.4729	0.0047	0.0812	0.366
	0.3328	0.4092	0.0990		.1331	0.2246	.5658	-0.0423	0.0492	0.390
	0.2733	0.4900	0.1023		.1093	.1845	.4646	-0.2097	-0.1345	0.145
	0.3166	0.4242	0.1023		.1266	.2137	.5382	-0.0833	0.0038	0.32
	0.2045	0.2517	0.0990		.0878	.1380	.3477	-0.0710	-0.0082	0.201
	0.1861	0.1283	0.1023		.0744	.1256	.3164	0.0299	0.0811	0.271
	0.1210	0.0042	0.0990		.0484	.0817	.2057	0.0662	0.0995	0.223
D	0.0868	- 0 -	0.1023		.0347	.0586	.1476	0.0192	0.0431	0.132
	2.2619	-2.1084	-1.2045		.9047	1.5267	3.8451	-0.1463	0.4995	2.81

	CUM. C1	CUM C2	CUM C3
J	0.0007	0.021	0.0964
	0.0116	0.0522	0.2033
	0.1003	0.2070	0.4693
	0.1333	0.2892	0.7348
	0.1380	0.3704	1.1011
	0.0957	0.4196	1.4915
	-0.1140	0.2851	1.6371
	-0.1973	0.2889	1.9654
	-0.2683	0.2807	2.1669
	-0.2384	0.3618	2.4388
	-0.1722	0.4613	2.6623
D	-0.1530	0.5044	2.7944

FIG. 15.6

Fig. 15a

Lake Level Elevations for 1963, 1980, 1981, 1982 and 1984

	P(ft)	PET(A)	C1M	C2M	C3M	LL1	LL2	LL3
1963								
January	0.0383	0	-0.0487	-0.0381	0.0051	-0.0487	-0.0381	0.0057
February	0.0342	0	-0.0445	-0.0351	0.0034	-0.0932	-0.0732	0.0091
March	0.0983	0.0108	0.0245	0.0516	0.1623	-0.0687	-0.0216	0.1714
April	0.1725	0.1258	0.0167	0.0641	0.2581	-0.0520	0.0425	0.4295
May	0.4217	0.2392	0.2489	0.3648	0.8391	0.1969	0.4073	1.2686
June	0.1592	0.4317	-0.3078	-0.2640	-0.0848	-0.1109	0.1433	1.1838
July	0.1275	0.4908	-0.4146	-0.2360	-0.0510	-0.5255	-0.0927	1.1328
August	0.1292	0.3933	-0.3147	-0.2792	-0.1339	-0.8402	-0.3719	0.9989
September	0.2892	0.2650	0.0409	0.1204	0.4458	-0.7993	-0.2515	1.4447
October	0.0675	0.2008	-0.2086	-0.1900	-0.1141	-1.0079	-0.4415	1.3306
November	0.0433	0.0300	-0.0684	-0.0565	-0.0078	-1.0763	-0.4980	1.3228
December	0.0500	0	-0.0323	-0.0185	0.0377	-1.1086	-0.5165	1.3605
1980								
January	0.0783	0	0.0073	0.0289	0.1169	0.0073	0.0289	0.1169
February	0.0558	0	-0.0143	0.0011	0.0638	-0.0070	0.0300	0.1807
March	0.0933	0	0.0283	0.0540	0.1589	0.0213	0.0840	0.3396
April	0.0692	0.1492	-0.1513	-0.1323	-0.0544	-0.1300	-0.0483	0.2852
May	0.1908	0.3208	-0.1560	-0.1035	0.1111	-0.2860	-0.1518	0.3963
June	0.4600	0.4042	0.1408	0.2673	0.7848	-0.1452	0.1155	1.1811
July	0.1917	0.5167	-0.3506	-0.2979	-0.0822	-0.4958	-0.1824	1.0989
August	0.2717	0.4192	-0.1411	-0.0664	0.2393	-0.6369	-0.2488	1.3382
September	0.3067	0.2400	-0.0904	0.1747	0.5198	-0.5465	-0.0741	1.8580
October	0.0550	0.0900	-0.1153	-0.1002	-0.0383	-0.6618	-0.1743	1.8197
November	0.0217	0.0217	-0.0903	-0.0844	-0.0844	-0.7521	-0.2587	1.7353
December	0.0200	0	-0.0743	-0.0688	-0.0688	-0.8264	-0.3275	1.665
1981								
January	0.0250	0	-0.0673	-0.0604	-0.0323	-0.0673	-0.0604	-0.0323
February	0.1783	0	0.1572	0.2063	0.4068	0.0899	0.1459	0.3745
March	0.0592	0.0392	-0.0586	-0.0423	0.0243	0.0313	0.1036	0.3988
April	0.1808	0.1533	0.0008	0.0505	0.2539	0.0321	0.1541	0.6527
May	0.1817	0.2708	-0.1187	-0.0688	0.1357	-0.0866	0.0853	0.7884
June	0.3683	0.4008	0.0158	0.1171	0.5314	-0.0708	0.2024	1.3198
July	0.3408	0.4592	-0.0844	0.0093	0.3927	-0.1552	0.2117	1.7125
August	0.3942	0.4042	0.0454	0.1538	0.5973	-0.1094	0.3655	2.3098
September	0.1217	0.2500	-0.1786	-0.1452	0.0083	-0.2884	0.2203	2.3180
October	0.2242	0.1075	0.1041	0.1657	0.4180	-0.1843	0.3860	2.7360
November	0.1800	0.0317	0.1213	0.1708	0.3733	-0.0630	0.5568	3.1093
December	0.0767	0	0.0051	0.0262	0.1125	-0.0579	0.6188	3.2218

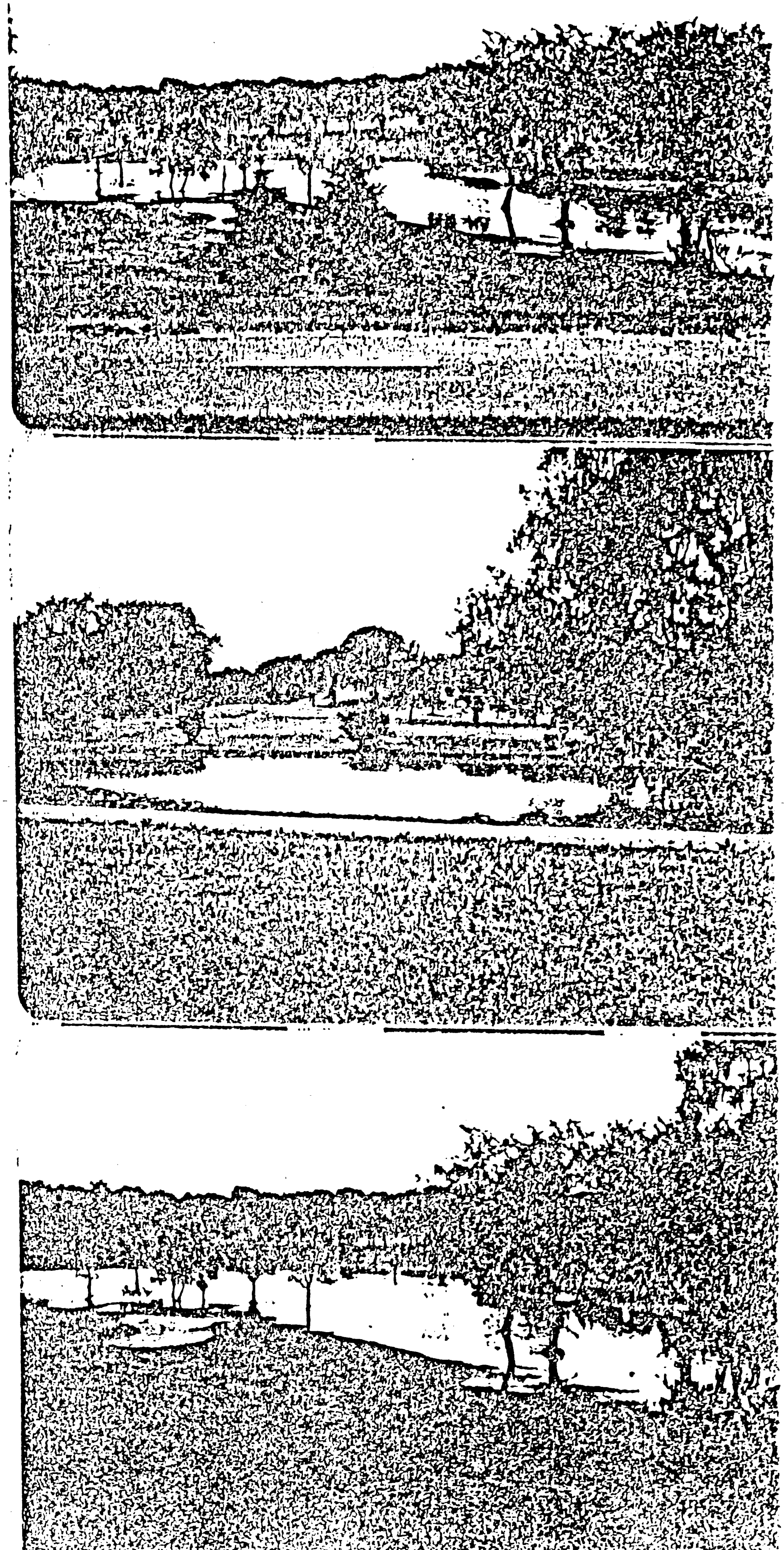
	P(ft)	PET(A)	C1M	C2M	C3M	LL1	LL2	LL3
1982								
January	0.2042	0	0.1836	0.2397	0.4695	0.1836	0.2397	0.4695
February	0.0358	0	-0.0423	-0.0324	0.0078	0.1413	0.2073	0.4773
March	0.1742	0	0.1416	0.1895	0.3855	0.2829	0.3968	0.8628
April	0.1350	0.0958	-0.0058	0.0313	0.1832	0.2771	0.4281	1.0460
May	0.4158	0.3342	0.1456	0.2600	0.7277	0.4227	0.6881	1.7737
June	0.1200	0.3525	-0.2835	-0.2505	-0.1155	0.3192	0.4376	1.6582
July	0.0767	0.5225	-0.5176	-0.4963	-0.4100	-0.3784	-0.0587	1.2482
August	0.3167	0.4333	-0.0922	-0.0051	0.3512	-0.4706	-0.0638	1.5994
September	0.1250	0.2550	-0.1790	-0.1446	-0.0040	-0.6496	-0.2084	1.5954
October	0.2875	0.1092	0.1910	0.2701	0.5935	-0.4586	0.0617	2.1889
November	0.2725	0	0.2825	0.3574	0.6640	-0.1761	0.4191	2.8529
December	0.3558	0	0.3958	0.4937	0.8939	0.2197	0.9128	3.7468
1984								
January	0.0733	0	0.0003	0.0205	0.1030	0.0003	0.0205	0.1030
February	0.1367	0	0.0990	0.1366	0.2903	0.0993	0.1571	0.3933
March	0.1225	0	0.0692	0.1029	0.2407	0.1685	0.2600	0.6340
April	0.3217	0.1300	0.2214	0.3098	0.6717	0.3899	0.5698	1.3057
May	0.1908	0.2542	-0.0894	-0.0369	0.1778	0.3005	0.5329	1.4835
June	0.6625	0.4342	0.3943	0.5765	1.3218	0.6948	1.1094	2.8053
July	0.2525	0.4758	-0.2246	-0.1552	0.1289	0.4702	0.9542	2.9342
August	0.4292	0.4567	0.0419	0.1599	0.6427	0.5121	1.1141	3.5769
September	0.2208	0.2183	-0.0082	0.0526	0.3010	0.5039	1.1667	3.8779
October	0.4567	0.1392	0.3979	0.5235	1.0372	0.9018	1.6902	4.9151
November	0.0167	0.0050	-0.0806	-0.0760	-0.0573	0.8212	1.6142	4.8578
December	0.1867	0	0.1591	0.2104	0.4204	0.9803	1.8246	5.2782

or 3 times larger than the lake (6.3 acres at 840 elevation). This relatively small lake could easily be filled and maintained with runoff from its own watershed and collected runoff from area PI, which has to be drained and pumped anyway if it is to be used as a golf course.

The flooding of the larger lake basin on the golf course in response to rainfall is demonstrated in Figure 16 where flooding conditions in the summer of 1984, a relatively wet year, are shown. A correlation between precipitation and pumpage was attempted by using the Park Board's energy consumption records. The data were collected by the Park Board and show a great deal of spurious variation (Fig. 17). In many instances winter month power usage, where no pumping is expected, is up to two orders larger than summer values. This may indicate that other power usage passes through the same recording device. Winter data could indicate heating operations. The high values might also reflect irregular billing or recording practices. Nevertheless when data (kwh) from the ice free months are plotted against precipitation still erratically high values occur, but ignoring the outliers a reasonable line can be drawn through the data points (Fig. 17). The slope of the line indicate a power usage of 37 kwh per inch of precipitation. The data are too unreliable at present to apply further analysis, but it is suggested that more precise methods be used to record pumpage power consumption and to separate it from other usages. Knowing the specific power vs discharge characteristics of the pump and its efficiency direct relations between water collected in the basin (and removed by pumpage), and precipitation could be carried out to establish a RO = f(P) correlation.

FIG. 16

Summer 1984



View is just north/northeast from St. Anthony Blvd in foregroun

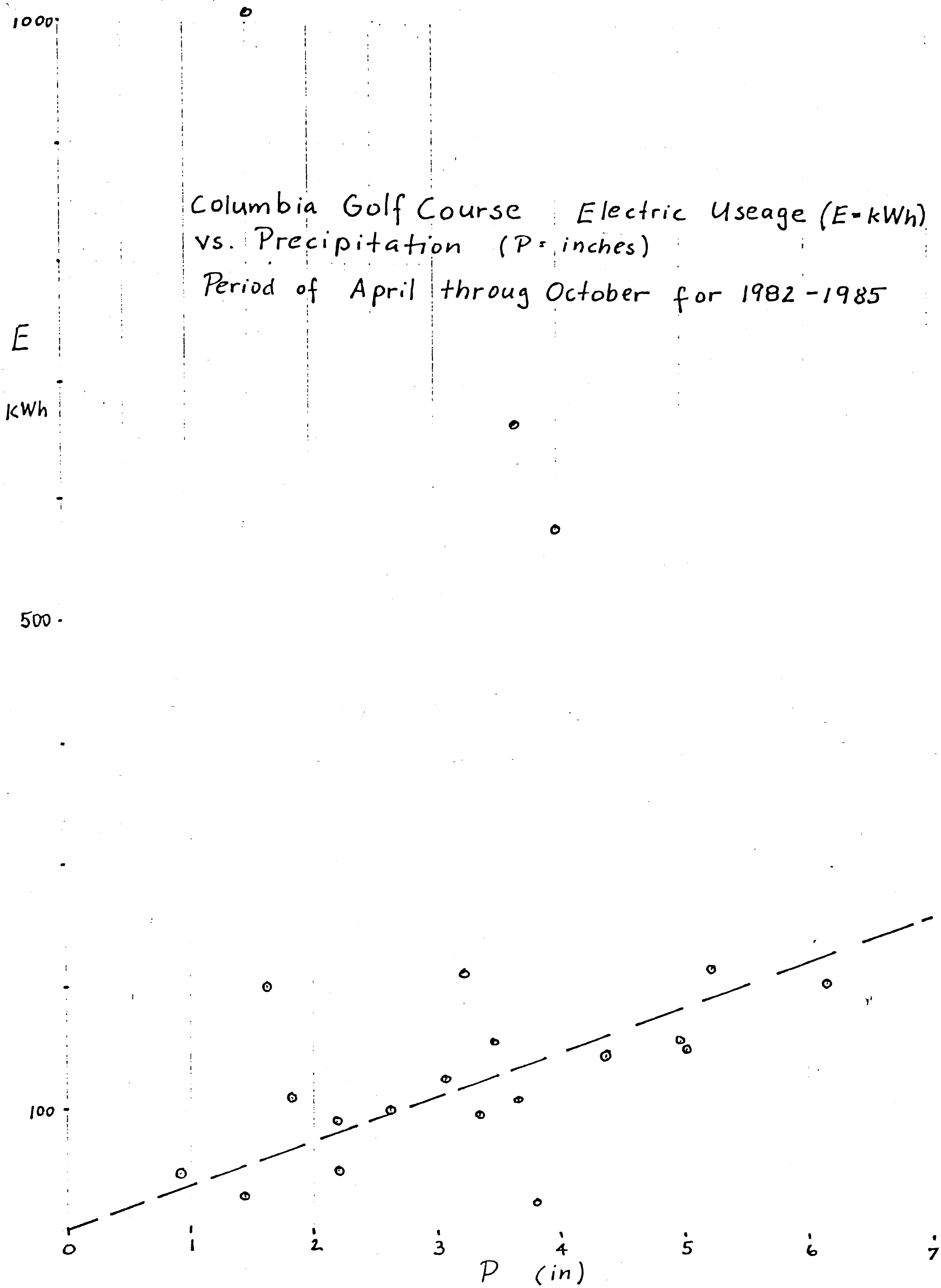

Columbia Golf Course Electric Useage (E = kWh)
vs. Precipitation (P = inches)
Period of April throug October for 1982-1985
1000
E
kWh
500
100
0
1
2
3
4
5
6
7
P (in)

FIG. 17.a

Electrical usage

1	2	1982	4	1983	6	1984	8	1985
Jan		2.45	313	.67	15	.88	2	.87
Feb.	1136	.43	238	1.21	647	1.64	305	.50
Mar	1011	2.09	215	3.22	195	1.47	762	4.48
A..	202	1.62	580	3.97	191	3.86	161	1.81
May	160	4.99	210	6.15	185	2.29	110	3.65
June	29	1.44	220	5.22	1142	795	92	2.18
July	47	.92	127	3.07	54	3.03	51	2.20
Aug.	25	3.80	216	3.12	122	515	153	5.02
SEPT	10[illegible]	1.50	99	3.34	96	2.65	148	4.37
OCT	160	3.45	102	2.61	348	548	665	3.66
NOV	224	3.27	166	4.93	14	0.0.2	(307)	
DEC	304	4.27	25	1.53	165	2.2.4		
	4365	30.23	2511	39.04	3174	36.84	(2449)	(28.74)

37.6 kWh/in precip.

FIG. 17.6

Feasibility of Lake Sandy Restoration

Summary of Results

The basic objectives of this study were to find the probable causes for the disappearance of the old Lake Sandy and to establish whether present climatic and hydrogeologic conditions would support restoration and maintenance of a lake in the former basin of Lake Sandy.

Causes: Analyzing the shrinkage of lake area with time as was done graphically in Figure 1, two statements can be made: Lake area seemed to have declined slowly between 1870 and 1900, this could be due to changes in the natural drainage system supporting the lake through urbanization. This would indicate that the lake in its quasi-natural state is dependent on surface runoff. The second portion of the curve marks a much steeper decline in lake area, possibly coinciding with the intensified efforts to artificially drain the lake and surrounding area. The one outlier in the data points is the 40 acre lake area reported in 1892. Measurements from reliable topographic surveys around this time contradict this number, and the evidence would be in favor of a larger lake area during this period. If there had been a problem of distinguishing between marshy areas and open lake this would surely have been indicated, at least on the USGS topographic map surveyed in 1899.

No compelling evidence was found in the records that massive filling of the lake basin took place. Some filling obviously was carried out at the southeastern end of the lake to increase the switch yard of the Soo Line, other filling occurred during the construction of St. Anthony Parkway, the construction of the golf course, and in additional unspecified locations in the park. The latter concerned about 2000 cubic yards at maximum which is only a tiny fraction of the lake volume.

Groundwater Seepage most probably is into the lake basin. Early reports and oral records speak of springs in the lake basin. It is, however, very difficult to judge the accuracy of those accounts. A permanent water body in the center of the basin at least seems to support some groundwater inseepage. A more definite assessment of the groundwater flow situation is only possible after more extensive investigation as outlined below.

Hydrometeorologic Balances seem to indicate that the climatic components are favorable to the maintenance of a lake under natural conditions. Only if the smallest defined watershed area (PI) contributes to runoff is supplementation of water through import from other sources needed in a normal year. Within a range of precipitation conditions, between approximately one standard deviation, both discharge as well as supplementation are needed.

Lake level fluctuations will be important and more noticeable in a relatively shallow lake (6.6 ft/2 m) and much of the physical lake management will have to be directed towards lake level stabilization.

Lake Restoration Procedures

The logical steps in lake restoration would consist of the preparation of the basin, filling of the lake and level maintenance procedures.

Preparation of the lake bed would consist of leveling and grading operations of the entire lake bottom, smoothing out of the shoreline to remove unsightly angulosities and promontories that would be subject to wave erosion, and to create a more pleasing aspect.

If lake bottom permeability conditions are estimated to be critical, working in of clay and till material into the bottom are feasible for smaller lakes.

Structural changes may be necessary such as retaining walls to maintain the integrity of the parkway, or seawalls to prevent erosion and cave-ins. This would especially be the case on the north side of St. Anthony Parkway which is only slightly elevated above the 840 and the 838 contour line and where the proposed lake would be very close to the road bed.

Filling of the Lake Basin

The volume of the basin contained below the 838 ft contour line is 11.5 million cubic feet or 86 million gallons of water. Natural infilling would take several years, especially if only the smaller watershed areas contribute to runoff. Therefore artificial supplementation is indicated. If a pump capacity of 1000 GPM were to be installed, 1433 hours of pumping would be necessary assuming no natural infilling. This corresponds to about 90 days of 16 hr pumping.

Supplemental water could be drawn from storm runoff generated by the larger watershed areas to the east and the north of the site. The water would have to be minimally treated because of the high nutrient concentration in urban storm runoff. Also the time for withdrawal would have to be selected appropriately to fall after the first peak of runoff which always carries the greatest nutrient load.

From a water quality point of view supplementation with deep groundwater would be more desirable. It would mean that one high capacity well (1000-1500 GPM) would have to be drilled and completed in the Prairie du Chien-Jordan formations. From existing information these aquifers should provide the necessary yield. The economic aspects of well construction and operation would have to be considered as part of the entire economic picture. It may also be envisaged to install a 500 GPM capacity well on site which would be used later for lake level maintenance and to use other wells from nearby, or pumpage from the Mississippi for the infilling process.

Lake Level Maintenance

From the preliminary balance calculations of the previous section it can be seen that over time some addition of water to the lake may become necessary to maintain lake levels. Because of the relatively small amounts the most desirable source would be deep groundwater, from the Prairie du Chien-Jordan aquifer with a relatively low installed well capacity of 500 GPM.

A problem of greater magnitude seems to be to keep the projected lake level down at 838 ft. For this pumping discharge would be necessary, but the present equipment may be sufficient for this purpose.

If the small basin south of St. Anthony Parkway were to be selected as the potential lake site both initial infilling and subsequent maintenance could easily be done by pumping the excess water from the golf course now discharged into the 31st Street sewer line into the basin itself.

Additional Information Needs

The previous discussion about the feasibility of restoring and maintaining a lake in portion of the old basin of Lake Sandy is based on a certain number of assumptions that need to be further tested. These assumptions deal with lake bed seepage and with the runoff contribution from different watersheds.

In order to assess the seepage into or out of a basin it is necessary to establish the direction of the groundwater potential gradient and the general flow direction of groundwater. This is best done by drilling three observation

(2-4 inch diameter) wells to the water table. From the water levels in the developed wells elevation of the water table and the general groundwater flow direction can be evaluated. This, however, is only a two-dimensional approach. In order to ascertain upward (inseepage) or downward (outseepage) components of flow it is necessary to use well nests. These consist of 2 to 3 wells that have been installed at the same location and screened at different depths. The position of the water level in the wells permits one to establish the magnitude and the direction of the gradient. For the site, two nests with three wells each are proposed. The shallowest well has a screen of about 5 to 10 ft set into the water table at approximately mid-screen to accommodate water table fluctuations. The other two wells with much shorter screen (2 ft) are set at 15 and 25 ft below the water table respectively. The two nests are to be installed one in a somewhat upstream position of the basin, i.e. to the east, the other downstream, i.e. near the western end of the basin. The third (water-table-only) observation well is to be placed such that an equilateral triangle is formed with the two nests for more convenient calculation of the water table slope.

During drilling of the wells sampling (split-spoon) should take place at 5 ft intervals, up to 25 ft for the hole nearest the center of the basin. The samples should be examined for grain size and sorting, nature of the material, and for possible permeability determinations. Knowing the gradient and the hydraulic conductivity or permeability permits an estimate of the actual seepage quantities according to Darcy's equation. If significant changes of lithology are observed a shorter sampling interval may be necessary. While drilling the other holes the drill cuttings should be closely observed to see if they correspond approximately to the lithology of the samples collected. If a great difference in lithology exists then samples should also be taken at the other boreholes.

For the basin south of St. Anthony Parkway probably only 3 water table wells are needed, one of which could serve as a nest with two 15 and 25 ft holes added. The nested well should be near the center of the basin.

Information from these exploration wells would give information about the inseepage-outseepage relations and whether the assumptions used in this report are valid.

The second area of concern is that of runoff generation and the efficiency of the artificial drainage system that has been installed and connected over time. To obtain information about this a series of controlled seepage experiments has to be carried out after rainfall and/or after spring snowmelt. The experiment would consist of measuring precipitation on the golf course with a recording rain gauge or evaporation pans. (All available from the Department of Geology and the Park Board.) This would give an idea of the atmospheric input-output, measurement of the elevation of water in the basin and its transformation into volume would give an idea about the runoff generated by a given precipitation. It would in a sense permit the calculation of runoff coefficients.

The other part of the experiment would be to record the recession of the water level with time under natural condition, i.e. no pumping. This would permit the calculation of an overall recession coefficient which would take into account both natural groundwater outseepage as well as drainage through the artificial drainage system. If this should prove to be much greater than assumed in this report suitable ways of de-activating the artificial drainage system would have to be instigated.

These seepage experiments, needless to say, would interfere with the use of the golf course. Possibly the best time to carry out one of them would be after snowmelt and before golf season starts.

Conclusions and Recommendations

The question whether physically and hydrologically a lake can be restored and maintained in portions of the basin that once held Lake Sandy has to be answered in the affirmative. This statement is based on the assumption of natural conditions. Phase 2 of the lake restoration study should investigate the actual groundwater flow conditions and the degree of artificial drainage in the old lake bed and its efficiency. Phase 2 should also look into the economics of the project in a more detailed fashion.

The future lake (northern site) will be relatively shallow. Its average depth will be 6.6 feet, about the same as Lake of the Isles of the Minneapolis Chain of Lakes, but its shape will be more compact. It would take a limnological feasibility study to determine the ultimate health of the future lake and the type of food chains and biological communities it could support.

From a hydrological point of view there seems no question that the southern segment of the old basin could easily be filled and maintained with runoff from its own watershed and from pumpage from the golf course. Its area and volume, however, would be much smaller than the potential northern lake (6 acres vs 40) and the limnological aspects would have to be looked at in more detail to ensure its biological feasibility.

Besides the physical-hydrologic and limnologic feasibility, the economic, sociologic, recreational and political tradeoffs will have to be considered by the appropriate government agencies before proceeding on this lake restoration project.

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